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HISTORICAL RADIOLOGICAL ASSESSMENT

NAVAL SUBMARINE BASE BANGOR

Volume I

NAVAL NUCLEAR PROPULSION PROGRAM

1973 - 1996

RADIOLOGICAL CONTROL OFFICE
PUGET SOUND NAVAL SHIPYARD
BREMERTON, WASHINGTON 98314-5001

May 1998

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1.0 **Executive Summary**

1.1 **Purpose**

This Historical Radiological Assessment (HRA) has been prepared by Puget Sound Naval Shipyard (PSNS) for Naval Submarine Base Bangor (Subase Bangor) pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the Superfund Amendments and Reauthorization Act of 1986 (SARA). The purpose of this HRA is to catalog and present over 20 years of radiological environmental data within the framework of the CERCLA process and within the pathway scoring protocol of the revised Hazard Ranking System (HRS).

Volume I of this HRA addresses radioactivity associated with the Naval Nuclear Propulsion Program (NNPP). Volume II addresses general radioactive material (G-RAM), including all non-NNPP applications of radioactivity (both Radiological Affairs Support Program (RASP) material and any site-related medical applications). Different branches of the Navy are responsible for these categories of radioactivity, and different historical practices have applied.

1.2 **Background**

Berthing facilities for nuclear powered submarines were completed at Marginal Wharf in 1963. Only minor radiological maintenance work (e.g., performed by Ship's Force) occurred at Bangor at that time.

Since November of 1973, the primary mission of Subase Bangor has been to provide support to the Trident Submarine Launched Ballistic Missile system, to provide administrative and personnel support for operations of the submarine force, and to provide logistical support for other Navy activities.

The Radiological Controls Department of Subase Bangor's new Trident Refit Facility (TRF) was established in January 1979. NNPP headquarters authorized TRF to perform radiological work in March 1982. The first Trident submarine arrived in August 1982.

In July 1973, before Trident Refit Facilities were constructed or any significant radiological work was performed at the site, a baseline study of the radiological environment of Subase Bangor and surrounding waters was conducted by PSNS. Radiological environmental monitoring by PSNS has continued through the present. Results are forwarded to the NNPP headquarters which, since 1966, has published an annual report with distribution to other Federal agencies, states, Congress, and the public.

Independent cross-checks of analytical results and independent surveys of the harbors have been an integral part of this program since its inception. These independent verifications have been consistent with NNPP and PSNS results and conclusions.

1.3 Findings

Since 1978, when new equipment gave improved specific radionuclide analyses, no radioactivity associated with Naval nuclear propulsion plants has been detected in harbor sediment, water, or marine life samples. Of all the radiological data collected by PSNS, the State of Washington Department of Social and Health Services (now the Department of Health), and the Environmental Protection Agency, no radioactivity associated with the NNPP has been detected in environmental samples. This has been confirmed by the findings of the Environmental Protection Agency (EPA) survey reported in 1989.

1.4 Conclusions

This HRA concludes that: (a) the berthing of and work on nuclear-powered ships at Subase Bangor has had no adverse effect on the human population or the environment of the region; and (b) independent reviews by the Environmental Protection Agency and the State of Washington are consistent with these conclusions. PSNS concludes that no additional characterization and no remedial actions are necessary as a result of NNPP activities at Subase Bangor.

SECTION 2.0

2.0 Introduction

2.1 Background

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 established a process whereby past private sector disposal sites were scored for environmental contamination, and remedial action initiated where warranted. Federal facilities were not included within CERCLA; however, under Executive Order 12316 of August 20, 1981, the President directed the Department of Defense (DOD) to conduct similar evaluations of their installations.

By the mid-1980's, most DOD facilities had been evaluated. These Initial Assessment Studies were conducted for Naval shipyards and operating bases where nuclear powered ships were maintained and berthed. The Initial Assessment Study (IAS) of Naval Submarine Base Bangor, Reference 1, was completed in 1983.

During 1986, DOD realigned its programs to be more consistent with those of the Environmental Protection Agency (EPA) in the private sector. Initial Assessment Studies paralleled the Preliminary Assessments and Site Inspections of CERCLA. Confirmation Studies paralleled the Remedial Investigation and Feasibility Studies of CERCLA.

The Superfund Amendments and Reauthorization Act (SARA) of 1986 required that federal agencies comply in the same manner and extent as private entities and allowed federal activities to be placed on the National Priorities List (NPL). Executive Order 12580 of January 23, 1987 gave additional jurisdiction to the EPA for federal facilities on the NPL.

SARA also directed the EPA to revise its Hazard Ranking System (HRS) used to score sites undergoing the CERCLA process. This was completed and the revised HRS was published in the Federal Register in December 1990.

The EPA scored Subase Bangor under the original Hazard Ranking System. Data collected during the 1983 IAS, Reference 1, was used in this scoring. Due to past chemical disposal and control practices, EPA proposed Subase Bangor for listing on the NPL on July 14, 1989. Subase Bangor was listed on the NPL on August 30, 1990. The 1983 IAS and the HRS scoring did not include consideration of any past releases of radioactivity associated with NNPP work since the emphasis during those efforts was on industrial and chemical pollutants.

2.2 Purpose

This Historical Radiological Assessment (HRA) was produced to provide a comprehensive review and assessment of the impact of radiological operations at Subase Bangor. This assessment is organized in a format similar to the standard Preliminary Assessment (PA) protocol used by the EPA within the CERCLA process. This format was chosen as a vehicle that is in common use and is easily understood.

Environmental radiological data collected for Subase Bangor is cataloged and presented within the pathway evaluation protocol of the PA. Additional environmental radiological data collected by the EPA and their independent conclusions are included in the relevant sections of this assessment.

Section 8 of this assessment addresses each pathway along with the salient data results contained in previous sections and evaluates estimates of radiological impact to the public and to the environment from Subase Bangor operations.

This assessment is historical in that the regulatory and policy changes that have occurred during the evolution of the NNPP are included as an explanatory supplement to the analytical results.

2.3 Methods

2.3.1 Counting Terminology

"Gross gamma" spectrometry systems used for counting environmental samples are currently calibrated to respond to gamma energies between 0.1 MeV and 2.1 MeV, and thus detect a combined total of all radionuclides with gamma energies between 0.1 and 2.1 MeV. (The gross gamma energy range for counting systems used from 1966 through 1973 was between 0.1 and 2.0 MeV). Similarly, "cobalt-60 energy range" gamma spectrometry is used to identify total gamma radioactivity in the range of 1.1 to 1.4 MeV. Where activity in this range is above 1 pCi/g, detailed radionuclide analysis is performed to determine whether cobalt-60 is present or whether all the activity is due to other (natural or fallout-related) radionuclides. For some analyses (e.g., modern environmental monitoring sediment, water, and biota samples), detailed radionuclide analysis is performed regardless of measured gamma levels.

Spectrometry detectors, whether sodium iodide or germanium, have conversion efficiencies which vary as a function of the incident gamma energy. This means that in order to determine the amount of a given radionuclide in a sample, the efficiency of the detector for that specific radionuclide would have to be determined using a known source of that radionuclide. Alternatively, a source containing known quantities of several radionuclides with gamma energies ranging from about 0.15 MeV to about 2.0 MeV can be used to construct an efficiency curve for the detector.

A simpler approach is to assign the efficiency for a particular radionuclide to all energies between the upper and lower limits of the region of interest. For the NNPP, cobalt-60 is the most predominant radionuclide and has the most restrictive concentration limit in air and water of all the radionuclides identified in Naval reactor plants. If all of the radionuclides with gammas occurring within a given band of energies are quantified by using the efficiency of the most limiting radionuclide, the resulting calculated quantity will conservatively overestimate the actual radioactivity for the radionuclide of concern.

Gross gamma, cobalt-60 equivalent is the quantity of all radioactivity in the gamma energy range of interest (0.1-2.1 MeV) calculated using the efficiency value of cobalt-60. Cobalt-60 energy range radioactivity is calculated using the cobalt-60 efficiency for all energies between 1.1 MeV and 1.4 MeV.

Natural background radionuclides generally have only one gamma per disintegration, of lower energy than cobalt-60's two gamma's (potassium-40 is an exception). Hence, actual background radioactivity is likely higher than measured and reported by this procedure. This is acceptable since background radioactivity is not of concern in these "gross gamma" and "cobalt-60 energy range" measurements. (This is also the basis for the term "cobalt-60 equivalent activity," since instruments are calibrated for pure cobalt-60 activity.)

When detailed radionuclide analyses are performed, germanium detectors are used. "Actual cobalt-60 radioactivity" or "specific cobalt-60" is the amount of cobalt-60 only, based on the counts in the 1.33 MeV photopeak and the efficiency of the detector at that photopeak using a known cobalt-60 source in a geometry equivalent to that of the sample.

2.3.2 The Investigatory Process

The pathways, targets, and potential release mechanisms described in this HRA were used to guide the process of selecting the information to be reviewed in preparing this assessment. During the course of the investigation, they were used to gauge the adequacy of the historical record of radiological work at Subase Bangor.

Information descriptive of Subase Bangor was in large measure taken from recent Navy Installation Restoration documents. Navy, PSNS, and Subase Bangor correspondence and history files were reviewed to ensure all potential source terms of radioactivity were identified. Navy, PSNS, and Subase Bangor historical records were reviewed to ensure that an accurate account is presented of past requirements and practices.

All available records related to release, monitoring, and waste disposal were reviewed to determine: where radiological work was performed; what the environmental impact of radiological operations has been; and the history of radioactive waste disposal. Records were reviewed to determine if any inadvertent releases of radioactivity to the environment were not immediately remediated. Records of areas formerly used for radiological work were reviewed to determine whether all such areas have been appropriately released from radiological controls in accordance with all applicable requirements. A more detailed discussion of the specific types of records reviewed, and the results of that review, are contained in Section 5.

2.3.3 Interviews

Interviews with about a dozen long-term and previous employees were conducted to examine whether the body of documented records is complete. Persons interviewed included the current Trident Refit Facility (TRF) Radiological Control Officer (1995 - 1996), his predecessor (1992 - 1994), and the first person assigned to the Radiological Controls Department at TRF (1979 - 1982). Interviews consisted of face-to-face discussions, telephone conversations, and electronic mail related to the employee's position, responsibilities, periods of employment, and involvement in selected elements applicable to the HRA. Employees were specifically questioned if any environmental releases had occurred that were not documented, whether any disposal of radioactive material had occurred on-site, and whether any radiological practices documented by historical records forming the basis of this HRA had changed. No cases of unreported environmental releases of radioactivity or unauthorized disposal of radioactive material were identified, nor were any past radiological practices reported to be different from those documented in this HRA.

2.3.4 Units

Units used throughout this report include: pCi/100 cm^2 (picocurie per 100 centimeters squared), pCi/g (picocurie per gram), kcpm (thousand counts per minute), µCi/ml (microcurie per milliliter), Ci/yr (Curie per year), mrem/hr (millirem per hour), and µR/hr (microroentgen per hour). A further explanation of a particular unit can be found in the glossary.

3.0 Site Description

3.1 Site Name and Location

Naval Submarine Base Bangor
1100 Hunley Road
Silverdale, WA 98315-1199
CERCLIS ID #: WA5170027291

Naval Submarine Base (Subase) Bangor is in Washington State, Kitsap County, in the northwestern portion of the Kitsap Peninsula. The base covers about 7,000 acres in the shape of an approximate rectangle, 6.5 miles north-south by 2.5 miles east-west. It includes five miles of shoreline on the east side of Hood Canal. A 678 acre buffer strip directly across Hood Canal on the Toandos Peninsula, once owned by the base, belongs to the Naval Undersea Warfare Engineering Station (NUWES), Keyport.

Subase is located near latitude 47° 44' 20" N and longitude 122° 44' 15" W. Figure 3-1 is a portion of four spliced 7.5 minute quadrangle maps for the Quilcene, Lofall, Poulsbo, and Seabeck quadrangles. Concentric circles of 1/4, 1/2, 1, 2, 3, and 4 mile radii are shown, using the base of Delta Pier as origin.

Figure 3-2 is a vicinity map of Subase. Figures 3-3 (a)-(c) are aerial photographs of the base's northern section. Figure 3-4 is a drawing of Subase identifying building numbers, pier and berth designations, etc.

The city of Poulsbo is about four miles east of Delta Pier. The residential community of Vinland is about two and one-half miles northeast. The town of Silverdale is about seven miles south-southeast. The largest city on the Kitsap Peninsula, Bremerton, is about twelve miles south-southeast.

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Figure 3-1
7.5 Minute Quadrangle Maps
Circles centered on base of Delta Pier
with radii of 1/4, 1/2, 1, 2, 3, and 4 miles

Figure 3-1
7.5 Minute Quadrangle Maps
Circles centered on base of Delta Pier
with radii of 1/4, 1/2, 1, 2, 3, and 4 miles


Bees Mill
State Shellfish Laboratory
Whitney Point
Camp Harmony
Tabook Pt
47°45'
T. 26 N.
Camp Parsons
(Boy Scouts)
Dock
Jackson Cove
Pulali Pt
Wawa Pt
BRINNON 4.5 MI.
NAVAL RESERVATION
NAVAL RESERVATION
HOOD CANAL
Brown Pt
Light
JEFFERSON CO
KITSAP CO
NAVAL UNDERSEA WARFARE ENGINEERING STATION
BANGOR ANNEX
Vinland
Vinland Church
North Kitsap High Sch
Poulsbo
Poulsbo Cemetery
Breakwater
Piers
Mud
Gravel
KINGSTON 8.5 MI.
270 000 FEET

Bees Mill
State Shellfish Laboratory
Whitney Point
47°45'
T. 26 N.
Camp Parsons
(Boy Scouts)
Jackson Cove
Pulali Pt
Wawa Pt
Camp Harmony
Tabook Pt
NAVAL RESERVATION
HOOD CANAL
Brown Pt
Light
JEFFERSON CO
KITSAP CO
NAVAL UNDERSEA WARFARE ENGINEERING STATION
BANGOR ANNEX
Kinland Church
North Kitsap High Sch
Poulsbo
Breakwater

Zelatched Pt
Tskutsko Pt
Hazel Pt
Oak Head
Coyle
Reservoir
Fisherman Harbor
Gravel
HAZEL POINT ROAD
T 26 N
T 25 N
DABOB
TOANDOS
HOOD CANAL
Bangor
Bangor Station
Olympic View
Guard Gate
Scandia
Pearson
Virginia
Pearson Cemetery
Island Lake
Cemetery
NAVAL UNDERSEA ENGINEERING
Mud
42'30"
40'
(BRINNON)

D A B
Zelatched Pt
42'30"
Tskutsko Pt
Coyle
HAZEL POINT ROAD
Hazel Pt
Reservoir
Fisherman Harbor
Oak Head
T 26 N
T 25 N
1479 III NW (BRINNON)
C A N A L
HOOD CANAL
Bangor
Guard Gate
Olympic View
Bangor Station
Substation
Trailer Park
Pearson Cemetery
Island Lake
Scandia
Pearson
Lemolo
Virginia
Overhead Cable
Keyport
NAVAL UNDERSEA WARFARE ENGINEERING STATION
B A Y
T. 26 N.
T. 25 N.
(SUQUAMISH) 1479 II NE
BAINBRIDGE ISLAND 3.1 MI.
WINSLOW (SEATTLE FERRY) 9.5 MI.

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Control by USC&GS and USCE

Topography from aerial photographs by Kelsh plotter methods
Aerial photographs taken 1951. Field check 1953

Hydrography compiled from USC&GS Charts 6422 and 6450

Polyconic projection. 1927 North American datum
10,000-foot grid based on Washington coordinate system, north zone

Dashed land lines indicate approximate locations

1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue

Revisions shown in purple compiled from aerial photographs taken 1968. This information not field checked

0°08' 2 MILS — 23° 409 MILS
UTM GRID AND 1968 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

DEPTH CURVES IN FEET—DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE AVERAGE RANGE OF TIDE IS APPROXIMATELY 7 FEET

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A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

WASHINGTON
QUADRANGLE LOCATION

Map photoinspected 1973
No major culture or drainage changes observed

ROAD CLASSIFICATION
Heavy-duty — Light-duty
Medium-duty — Unimproved dirt

SEABECK, WASH.
NE/4 POINT MISERY 15' QUADRANGLE
N4737.5—W12245/7.5
PHOTOINSPECTED 1973
1953
PHOTOREVISED 1968
AMS 1479 III NE—SERIES V891

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Topography by photogrammetric methods from aerial photographs taken 1951. Field checked 1953

Selected hydrographic data compiled from NOS charts 6445 and 6446
This information is not intended for navigational purposes

Polyconic projection. 10,000-foot grid ticks based on Washington coordinate system, north zone. 1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue. 1927 North American Datum. To place on the predicted North American Datum 1983 move the projection lines 23 meters north and 94 meters east as shown by dashed corner ticks

There may be private inholdings within the boundaries of the National or State reservations shown on this map

0°14' 4 MILS — 21° 373 MILS
UTM GRID AND 1981 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES IN FEET—DATUM IS MEAN LOWER LOW WATER
THE RELATIONSHIP BETWEEN THE TWO DATUMS IS VARIABLE
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE AVERAGE RANGE OF TIDE IS APPROXIMATELY 7 FEET IN HOOD CANAL
AND 8 FEET IN LIBERTY BAY AND DYES INLET

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
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WASHINGTON
QUADRANGLE LOCATION

Revisions shown in purple and woodland compiled from aerial photographs taken 1978 and other sources. This information not field checked. Map edited 1981

Purple tint indicates extension of urban areas

ROAD CLASSIFICATION
Medium-duty — Light-duty
Unimproved dirt
State Route

POULSBO, WASH.
N4737.5—W12237.5/7.5
1953
PHOTOREVISED 1981
DMA 1479 II NW—SERIES V891

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Control by USC&GS and USCE

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Hydrography compiled from USC&GS Charts 6422 and 6450

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Revisions shown in purple compiled from aerial photographs taken 1968. This information not field checked

GN MN 0°08' 2 MILS 23° 409 MILS

UTM GRID AND 1968 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

DEPTH CURVES IN FEET—DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE AVERAGE RANGE OF TIDE IS APPROXIMATELY 7 FEET

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ROAD CLASSIFICATION

Heavy-duty Light-duty
Medium-duty Unimproved dirt

WASHINGTON
QUADRANGLE LOCATION

Map photoinspected 1973
No major culture or drainage changes observed

SEABECK, WASH.
NE/4 POINT MISERY 15' QUADRANGLE
N4737.5—W12245/7.5
PHOTOINSPECTED 1973
1953
PHOTOREVISED 1968
AMS 1479 III NE—SERIES V891

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Topography by photogrammetric methods from aerial photographs taken 1951. Field checked 1953

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GN MN 0°14' 4 MILS 21° 373 MILS

UTM GRID AND 1981 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES IN FEET—DATUM IS MEAN LOWER LOW WATER
THE RELATIONSHIP BETWEEN THE TWO DATUMS IS VARIABLE
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE AVERAGE RANGE OF TIDE IS APPROXIMATELY 7 FEET IN HOOD CANAL
AND 8 FEET IN LIBERTY BAY AND DYES INLET

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
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QUADRANGLE LOCATION

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Purple tint indicates extension of urban areas

ROAD CLASSIFICATION

Medium-duty Light-duty
Unimproved dirt
State Route

POULSBO, WASH.
N4737.5—W12237.5/7.5
1953
PHOTOREVISED 1981
DMA 1479 II NW—SERIES V

Figure 3-2
Naval Submarine Base Bangor, Vicinity Map

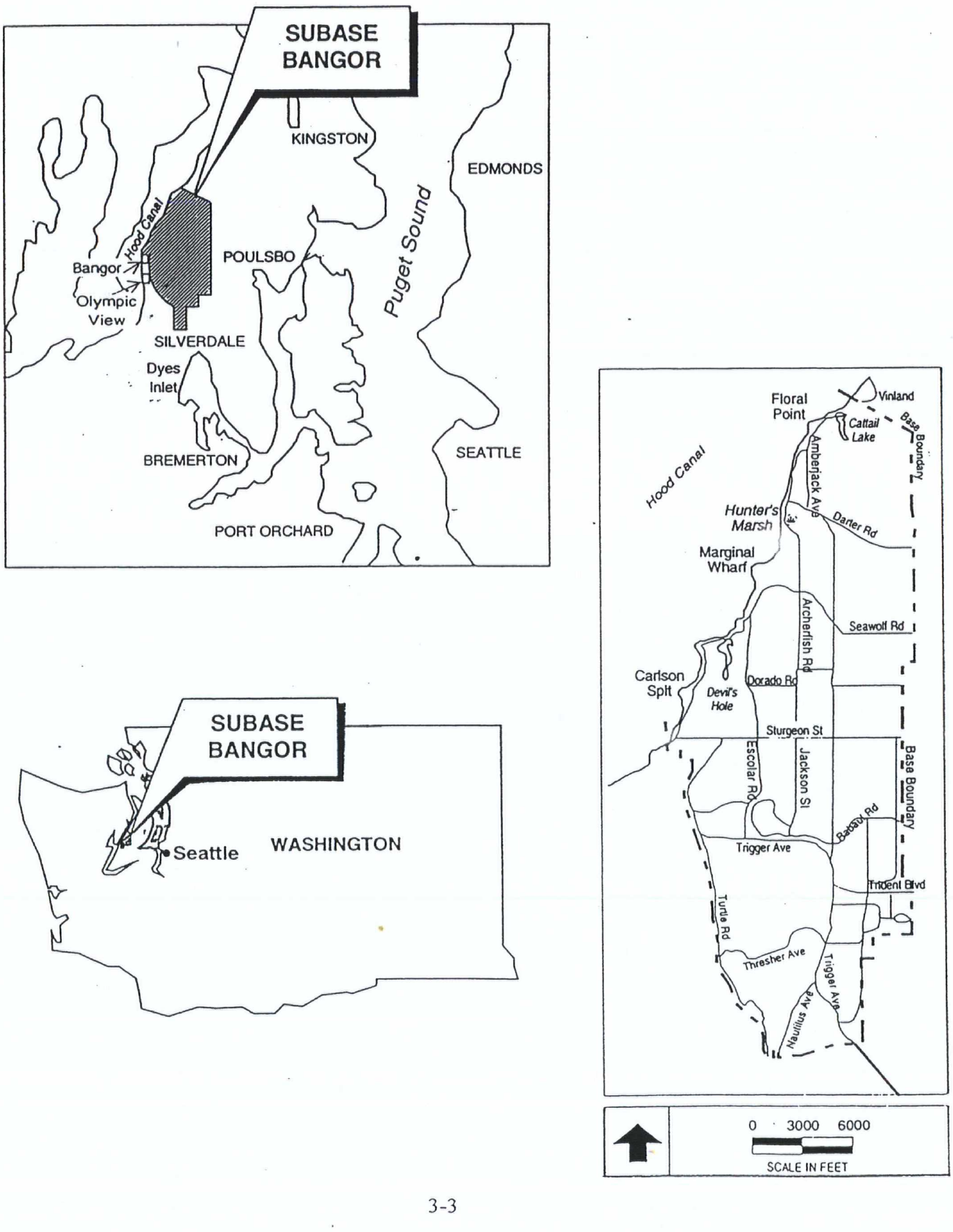
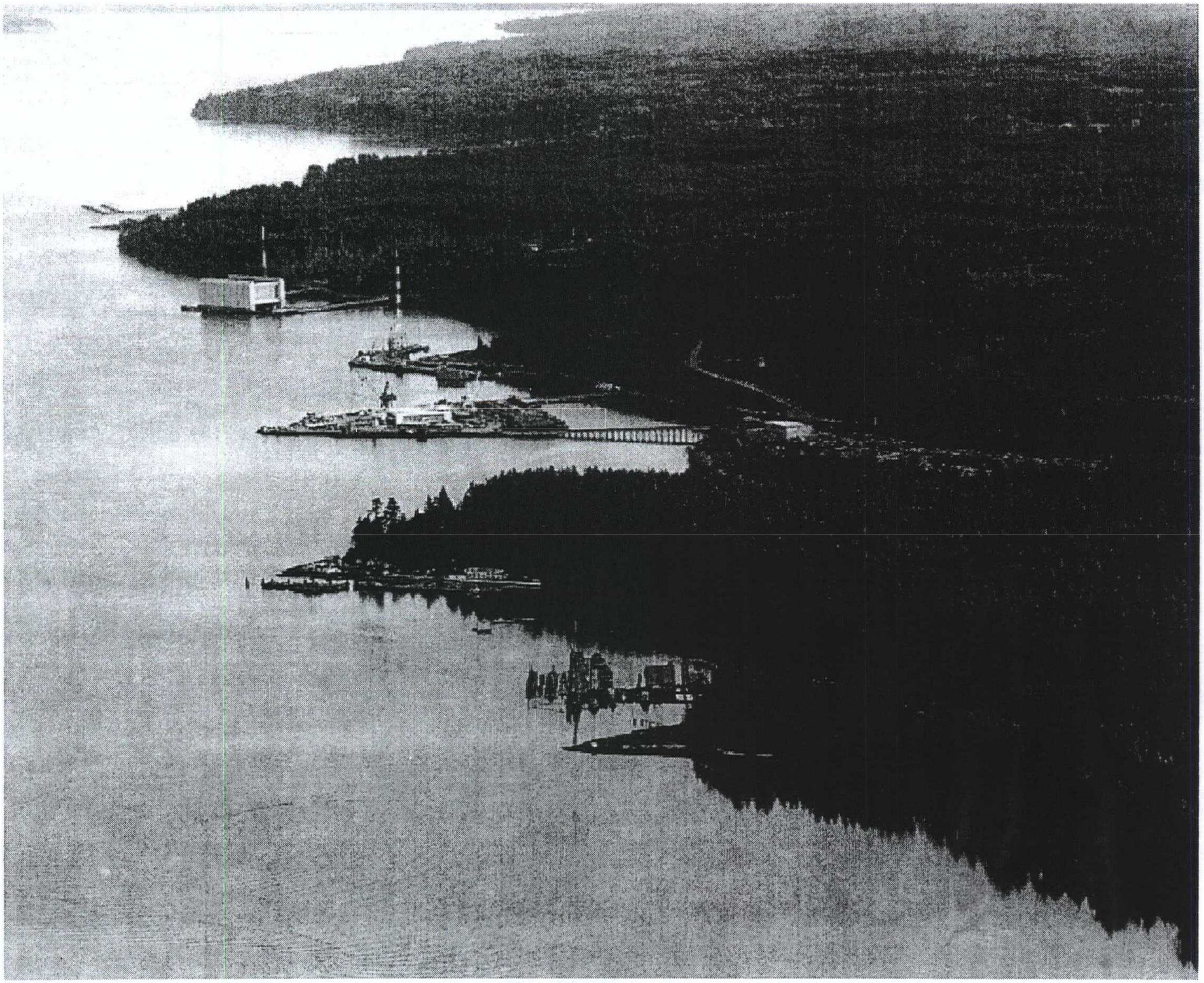


Figure 3-3 (a)



Looking northeast along Hood Canal.

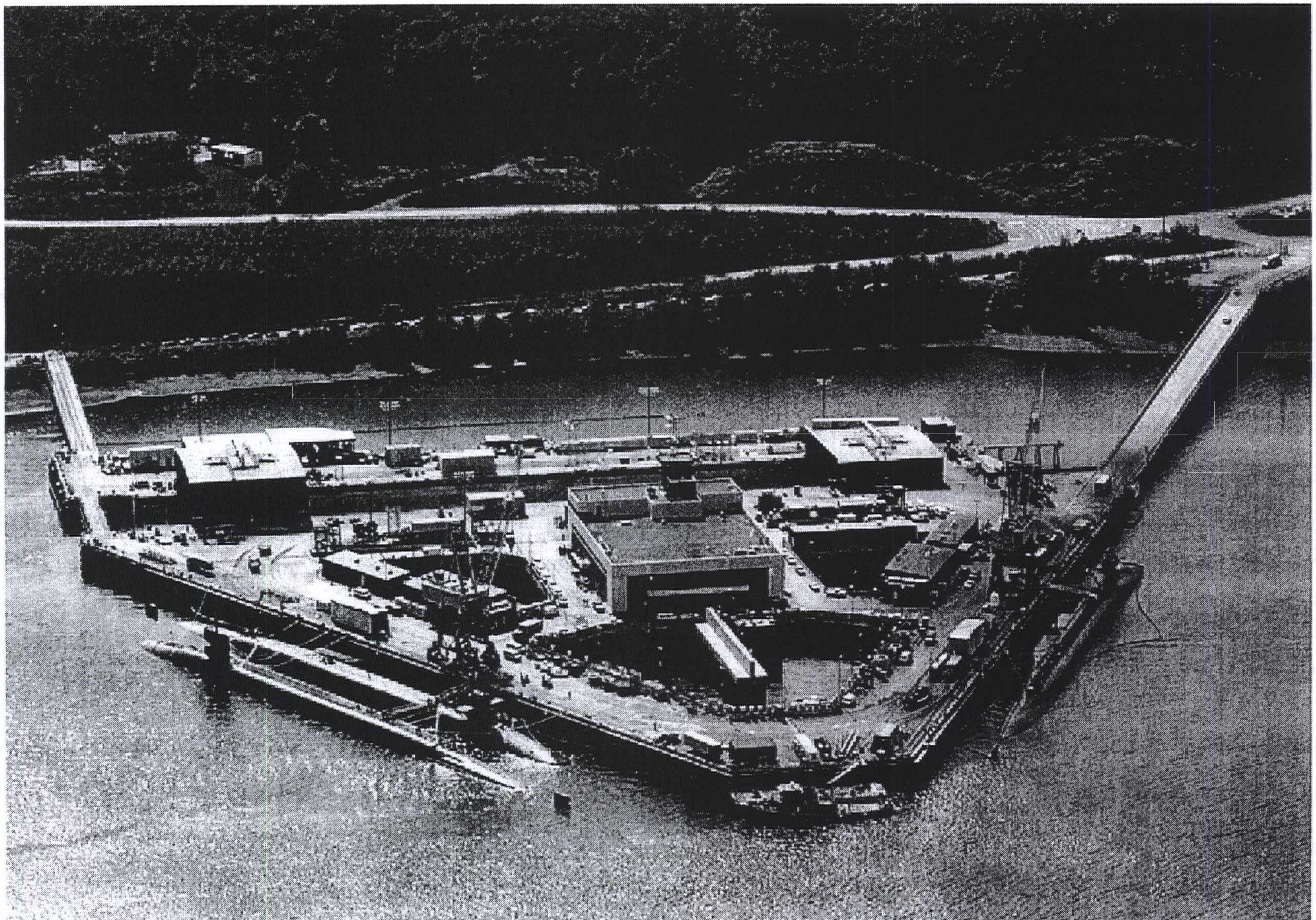
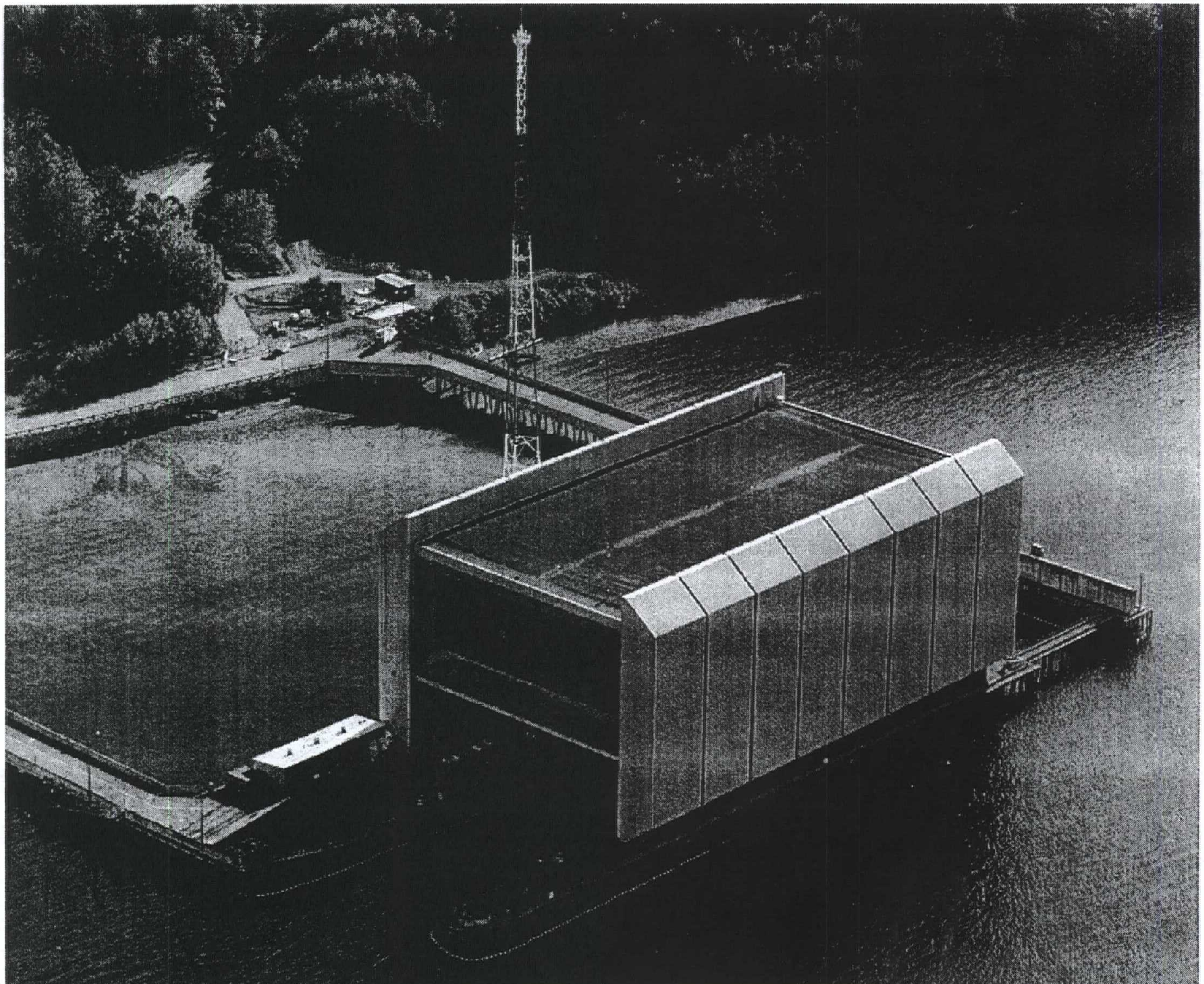


Figure 3-3 (b)

Delta Pier. Looking east.

Figure 3-3 (c)



Explosive Handling Wharf. Looking southeast.

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Figure 3-4
Naval Submarine Base Bangor, Site Map

NN
MM
LL
KK
JJ
HH
GG
FF
EE
DD
CC
BB
AA
Z
Y
X
W
V
1
2
3
4
5
6
7
SCHOOL PROPERTY
OLYMPIC VIEW ROAD
TURTLE ROAD
NAUTILUS AVENUE
GATE 5
THRESHER AVE
GRAMPUS ROAD
ATHLETIC FIELD
PLAYGROUND
CAPELIN DRIVE
GRENADIER DRIVE
SWFPAC SUPPORT
HEATING PLANT
SKIPJACK CIRCLE
TRIGGER AVENUE
RESERVOIR
ESCOLAR ROAD
ROOSEVELT
PLUNGER STREET
SNOOK ROAD
FINBACK CIRCLE
HEATING PLANT
7001
SWSMS
SUBMART
PARKING
SUBSTA 3
ALLEN
STREET
JACKSON STREET
STURGEON

8
9
10
11
12
13
14
NN
MM
LL
KK
JJ
HH
GG
FF
EE
DD
CC
BB
AA
Z
Y
X
W
V
U
SOUTHEAST FAMILY HOUSING
TRIGGER AVENUE GATE
SOUTHERN BOUNDARY ROAD
SCORPION AVENUE
TRIGGER AVENUE
FLEET DEPLOYED PARKING AREA
HELIPAD
OPERATIONAL AREA GATE
LAFAYETTE STREET
FLIER ROAD
LAKE RUTH
SEWAGE
LAGOONS
NUWC ORDNANCE ANNEX
GROUP 4
GROUP 6
GROUP 8
GROUP 10
DACE ROAD
ASPRO
PUFFER ROAD
HADDO ROAD
TREPANG
KETE ROAD
TRANSHIPMENT FACILITY
PUBLIC WORKS
ATHLETIC FIELD
BOSC PARKING
HUNLEY ROAD
ADMINISTRATION
PARKING
SUNFISH DRIVE
MAIN GATE
RESERVE CENTER
EASTERN BOUNDARY ROAD
SUBSTA 1
CLEAR CREEK ROAD
GATE 1
WEBSTER ST.
HENRY
STIMSON ST.
HAMILTON ST.
KEY ST.
FIRE
ATHLETIC FIELD
DISPENSARY
TULLIBEE CIR.

OCTOBER 14, 1997
JACKSON STREET
STIMSON STREET
VON STEUBEN STREET
LAFAYETTE STREET
HAMILTON STREET
KEY STREET
TECUMSEH
JEFFERSON
ARCHERFISH ROAD
SSP ARCHERFISH STORAGE COMPOUND
SEAWOLF
FLIER ROAD
BULLHEAD ROAD
SCORPION AVENUE
GURNARD ROAD
TREPANG ROAD
EASTERN BOUNDARY ROAD
GROUP 10
GROUP 12
GROUP 14
NUWC ORDNANCE ANNEX
OPEN STORAGE
EDISON STREET
ADAMS STREET
CLAY STREET
WILSON AVENUE
WILSON STREET
GATE 9
PARKING
CLEAR CREEK
POGY ROAD
DARTER ROAD
SUBSTA.
AMBERJACK AVE.
AMBERJACK ROAD
AMBERJACK AVENUE
TANG ROAD
FLORAL POINT
MSF
MSSF
CATTAIL LAKE
TINOSA ROAD
150,000 Gallon Tanks
Pre-fabricated metal Bldg.
PINTADO ROAD
EOD TEST RANGE
WILKES MARSH
NORTH BOUNDARY ROAD
8
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10
11
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14
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3.2 Site History

3.2.1 Type of Site

Subase Bangor is a U.S. Navy submarine base. The base, along with its tenant activities, provides intermediate level maintenance, alterations, repairs, and testing on U.S. Navy submarines; home porting of submarines and their crews; and training for submarine personnel. Most of the developed land is in the southern half of the base. The core area is at the extreme southern end of the base with family housing and a community center. The public works and administrative areas are east of the core area. Additional family housing is located west of the core area. Industrial facilities are located throughout the rest of the base. Waterfront facilities are located along the length of the shoreline. The northern part of the base is densely forested and mostly undeveloped. The Bangor site is isolated and is a natural deep water harbor, which permits large ships to tie up at dockside.

In addition to the Trident Refit Facility (TRF), major tenant commands include:

- Submarine Group Nine and Submarine Squadron Seventeen - Submarine fleet commands
- Trident Training Facility for submarine crews and TRF personnel
- Home ported Trident submarines
- SWFPAC - Strategic Weapons Facility, Pacific
- Marine Corps Security Force

3.2.2 Navy Ownership History

On June 5, 1944 the Navy bought 7,676 acres of land on Hood Canal for construction of the U.S. Naval Magazine, Bangor. Before Navy acquisition, the property included a few private dwellings and small farms. The activity was commissioned in August 1945 as the U.S. Naval Magazine Facility, and in 1947 was redesignated the U.S. Naval Ammunition Depot (NAD), Bangor.

NAD Bangor was established by the Navy to provide a deep water transshipment point for ammunition and explosives. NAD Bangor's mission was to receive, renovate, maintain, store, and issue ammunition, explosives, expendable ordnance items, weapons, and technical ordnance material.

For purposes of economy following World War II, NAD Bangor was disestablished and consolidated with the U.S. Naval Torpedo Station (NTS), Keyport, Washington, in July 1950. Following this change, the Depot operated under the management of the U.S. Naval Ordnance Depot, Puget Sound, Keyport, Washington. The consolidation of two dissimilar activities did not prove adequate to meet the requirements and demands placed upon it. Therefore, NAD Bangor was re-established in April 1952 as an independent operating activity.

In 1962, construction of the Polaris Missile Facility Pacific (POMFPAC) was begun. Submarine facilities, including berthing for nuclear-powered ships, were completed in 1963. POMFPAC was commissioned as a tenant at NAD Bangor in September 1964.

Although the date a nuclear ship first visited Bangor is not known, it was likely no earlier than 1963 when the support facilities were completed at Marginal Wharf.

In 1970, NAD Bangor was disestablished and consolidated under command of NTS, Keyport, as the Bangor Annex. Bangor Annex was selected as the Underwater Launched Missile System (ULMS; now Trident) support site for the Underseas Long-Range Missile System refit complex in January 1973. In 1974, POMFPAC was renamed the Strategic Weapons Facility, Pacific (SWFPAC) and its scope was enlarged to include support of TRIDENT missiles.

Construction of the Trident support site began in October 1974. This included construction of the Trident Refit Facility which includes the Delta Pier and drydock complex and the Controlled Industrial Facility (CIF), Building 7201. The Trident support site was commissioned as Naval Submarine Base (Subase) Bangor in February 1977. NTS Keyport was redesignated Naval Undersea Warfare Engineering Station (NUWES), Keyport, in 1978.

Trident Refit Facility's Radiological Controls Department started in January 1979. NNPP headquarters authorized the Trident Refit Facility to perform radioactive work in March 1982. The first Trident submarine to be based here was USS OHIO (SSBN 726), which arrived in August 1982.

3.2.3 **Site Activities** (Reference 2)

The site has been a Naval ammunition depot since 1945. Ammunition depot activities include loading and off-loading equipment, supplies, and ammunition from Naval vessels; and ammunition inspection, storage, and transshipment.

U.S. Naval nuclear-powered submarines have visited Subase Bangor since the early 1960's. Until 1972 when the Navy prohibited radioactive discharges in harbors, nuclear submarines visiting Bangor may have discharged into Hood Canal (See Section 5.1.1.1). Until the Trident Refit Facility (TRF) received its authorization to perform radioactive work in March 1982, only limited radioactive work was performed at Bangor, by either ship's personnel or Puget Sound Naval Shipyard.

Since November of 1973, the primary mission of Subase Bangor has been to provide support to the Trident Submarine Launched Ballistic Missile system, to provide administrative and personnel support for operations of the submarine force, and to provide logistical support for other Navy activities.

In the specific case of Naval Nuclear Propulsion Program work, which is the focus of Volume I of this HRA, all of the engineering disciplines, trade skills, quality assurance inspectors, and radiological control personnel are available to accomplish electrical and mechanical services to nuclear propulsion plants. These range from simple valve repairs to complex nuclear ship alterations. A few of the typical services performed are listed below:

- Minor valve repair
- Major valve overhaul or replacement
- Piping system repair or alteration

- Calibration of mechanical and electrical measuring equipment
- Motor and generator overhaul
- Repair and calibration of electrical equipment
- Test and inspection of components and systems
- Off-hull resin discharge

Numerous activities support this work such as nuclear engineering and planning, supply, radiological controls, quality assurance, machine shops, and administrative groups required to plan and execute tasks as complex as maintaining a nuclear-powered warship.

3.3 Site Description

3.3.1 Site Land Use

The physical features of Subase are discussed above and shown in Figure 3-4. Less than 20 percent of the base surface area is covered by buildings, other structures, and pavement. Subase Bangor is divided into two functional sections, north and south. The southern section (non-industrial area) of the base is generally administrative and Navy housing. The northern section (industrial area) is used for military operations.

All of the piers, drydock, and work facilities used to accomplish Naval Nuclear Propulsion Program work are within the northern section. Radioactive material shipments traverse the southern section but are stored within the northern section. As a result of this division, the southern section is not considered a potential source of NNPP radioactivity entering the environment.

Since most of the work that is accomplished on the reactor plant is done onboard the ship, Subase Bangor facilities dedicated to radiological work are relatively small. Section 5.5 lists the facilities used for radiological work and used to store radioactive material. The primary radiological work facility is contained within the Controlled Industrial Facility (CIF), Building 7201, south of Delta Pier, and totals less than 15,000 square feet. See Figure 3-4.

Buildings 7417, 7429, 7431, and 7432 are small buildings on Delta Pier used to provide weather protection for portable primary coolant collection tanks, and for temporary storage of radioactive materials associated with ongoing work on submarines.

In addition to the Delta Pier/Drydock complex, Naval nuclear vessels may berth at the Magnetic Silencing Facility (Degaussing Pier), the Explosive Handling Wharf, Marginal Wharf, Small Craft Pier (K/B Dock), or the Service Pier.

The remaining buildings in the northern section are shop areas, warehouses, and administrative areas that do not contain radiological material associated with the Naval Nuclear Propulsion Program. Open paved areas are used for storage of non-nuclear materials and large equipment associated with ship repair functions.

3.3.2 **Demography and Adjacent Land Use**

Adjacent to the base the country is primarily residential/semirural. Figure 2-11, Land Use Map, of Reference 3 is a detailed color-coded land use map of Kitsap County.

The population of Kitsap County in 1990 was 189,731. The following table of estimated population since 1980 shows a pattern that is largely caused by variations in Navy personnel. The estimates were made on April 1 of each year.

Table 3-1
Kitsap County Population

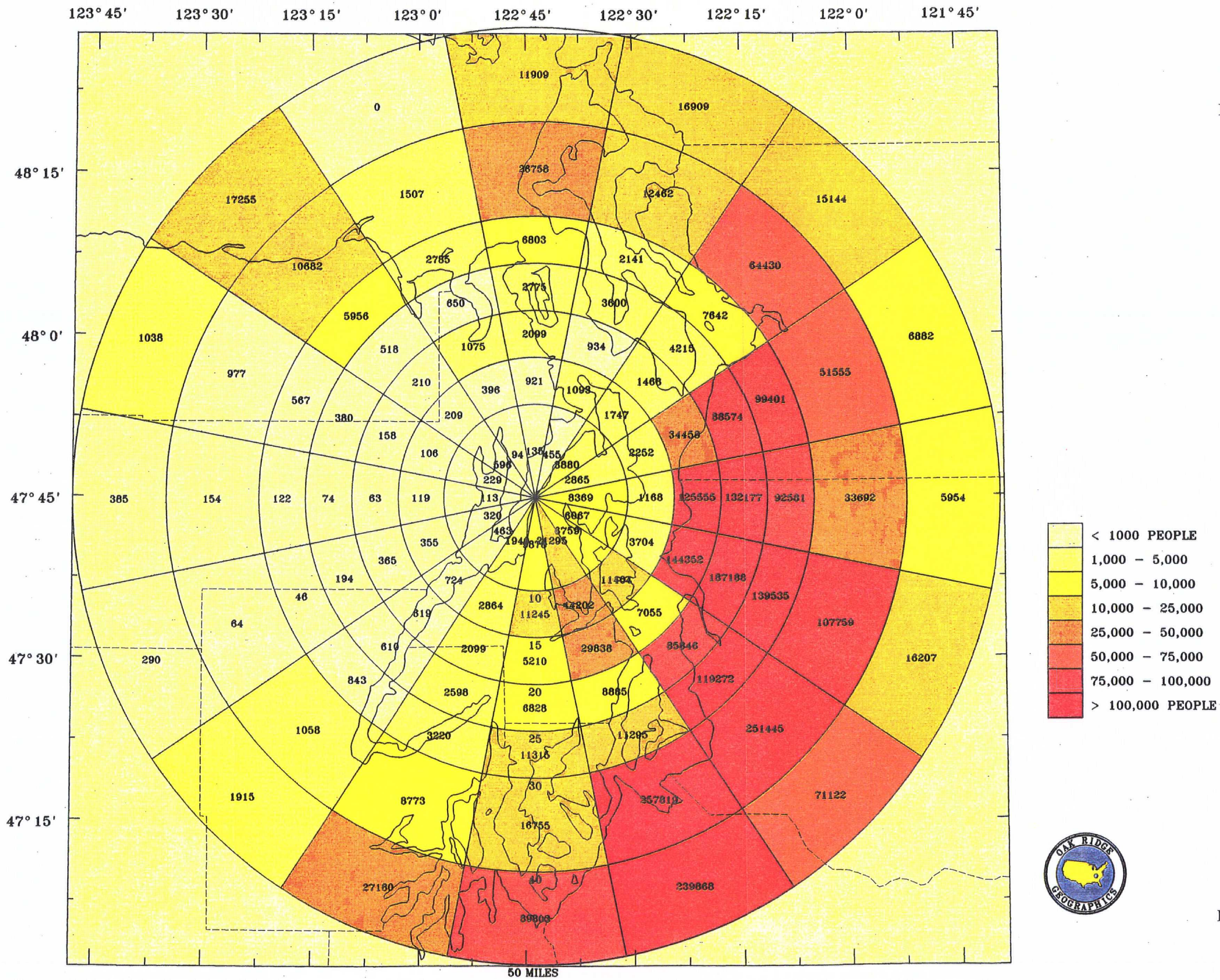
Year	Kitsap County
1980	147,152
1981	156,800
1982	158,500
1983	161,600
1984	162,500
1985	167,800
1986	164,500
1990	189,731

In 1990 the resident Subase Bangor population was 3702. Populated areas near Subase Bangor include the cities of Poulsbo, Keyport, and Silverdale. Small residential communities near the base include Bangor, Vinland, and Olympic View. Bremerton is the largest city in the county with a population of 37,645 in 1992.

At the time of the 1990 census, approximately 2.87 million persons resided within the 50-mile radius from the Subase, with 63,458 within 10 miles.

Figures 3-5 and 3-6 are computer generated constructs of 7.5 minute maps with the population by standard zone and sector divisions overlain. A zone is a 22.5 degree arc with Zone "A" centered on geographic north and Zones B, etc., increasing clockwise. A sector is a one-mile, five-mile, or ten-mile annular segment. Population data is based on the 1990 census data.

1990 Regional Population - SUBABG
POPULATION COUNT BY SECTORS AND ANNULI - SUBASE - BANGOR
1990 Census



Prepared by Geographic Data Systems Group of CAD

3-16-94

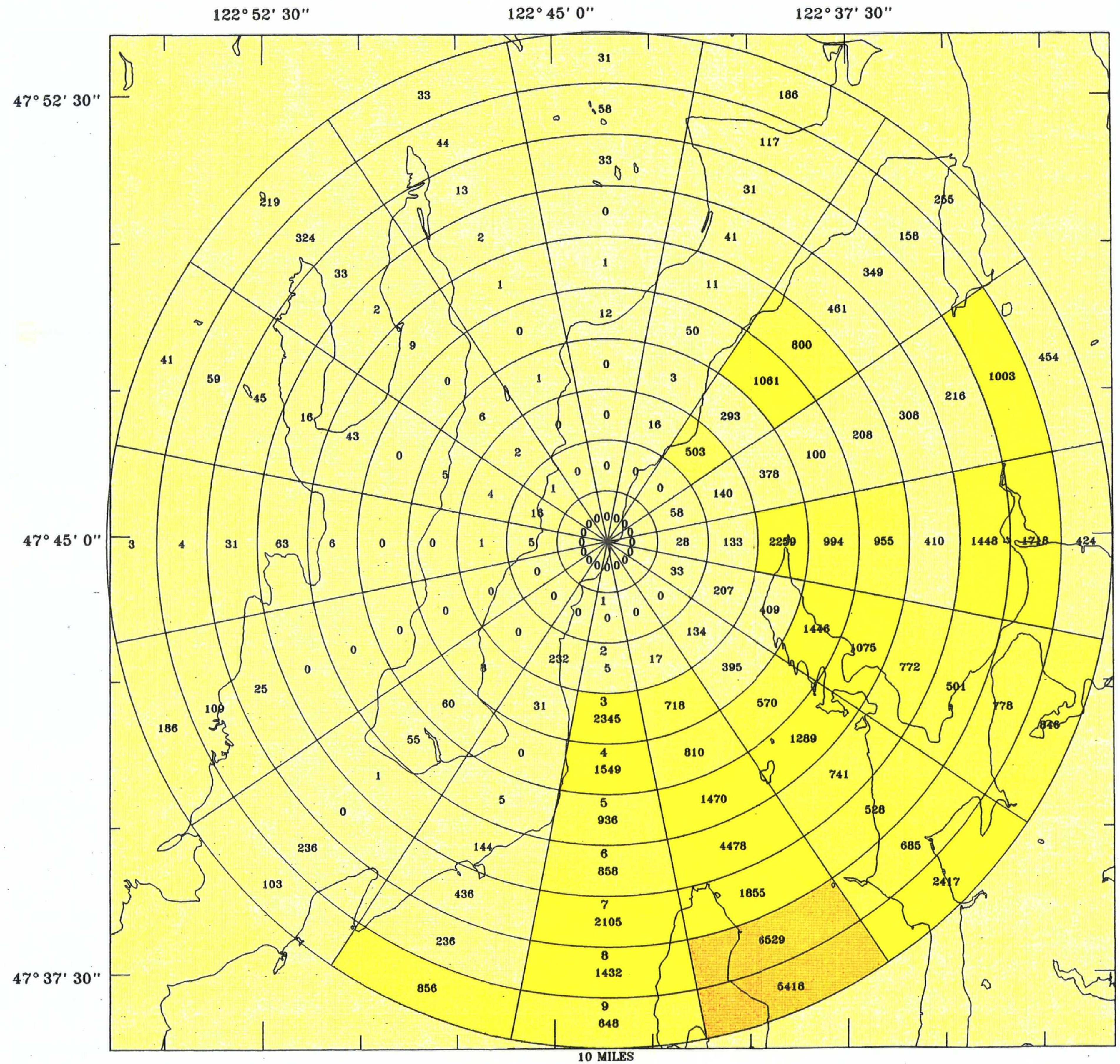
Population in 10-mile circle

Zone	Population
N	135
NNE	455
NE	3880
ENE	2865
E	8369
ESE	6067
SE	6759
SSE	21295
S	9878
SSW	1940
SW	463
WSW	320
W	113
WNW	229
NW	596
NNW	94

OAK RIDGE GEOGRAPHICS

Figure 3-5
Fifty Mile Population Density

1990 Local Population - SUBABG
POPULATION COUNT BY SECTORS AND ANNULI - SUBASE - BANGOR
1990 Census



< 500 PEOPLE
500 - 1,000
1,000 - 5,000
5,000 - 10,000
10,000 - 15,000
15,000 - 25,000
25,000 - 50,000
> 50,000 PEOPLE

Prepared by Geographic Data Systems Group of CAD

3-16-94

Figure 3-6
Ten Mile Population Density

3.3.3 **Physical Characteristics**

This section describes Subase Bangor's physiographic setting, soils, geology, hydrogeology, and seismology as they relate to infiltration of contaminants into ground waters, mobility and transport via the ground water, and confining features that inhibit area-wide distribution of introduced potential contaminants. The transport and distribution of materials in the local ground water is, in part, a function of the local and regional geological morphology and stratigraphy.

3.3.3.1 **Geology** (Reference 2)

Subase Bangor is located on the west side of the Kitsap Peninsula, at the western edge of the central Puget Sound Lowland (also known as the Puget Trough, see Figure 3-7). The lowland is part of a regional north-south trending structural trough extending from the Fraser River Valley in British Columbia to Eugene, Oregon. The Puget Sound Lowland is bounded on the east by the Cascade Range and on the west by the Olympic Mountains. The Kitsap Peninsula separates Puget Sound from Hood Canal, a fjord-like embayment of marine water extending southward from the western end of the Strait of Juan de Fuca. Opposite the base, the Olympic Mountains on the western side of Hood Canal rise to elevations exceeding 8,000 feet, imposing a strong orographic (rain shadow) effect on the regional Pacific maritime climate.

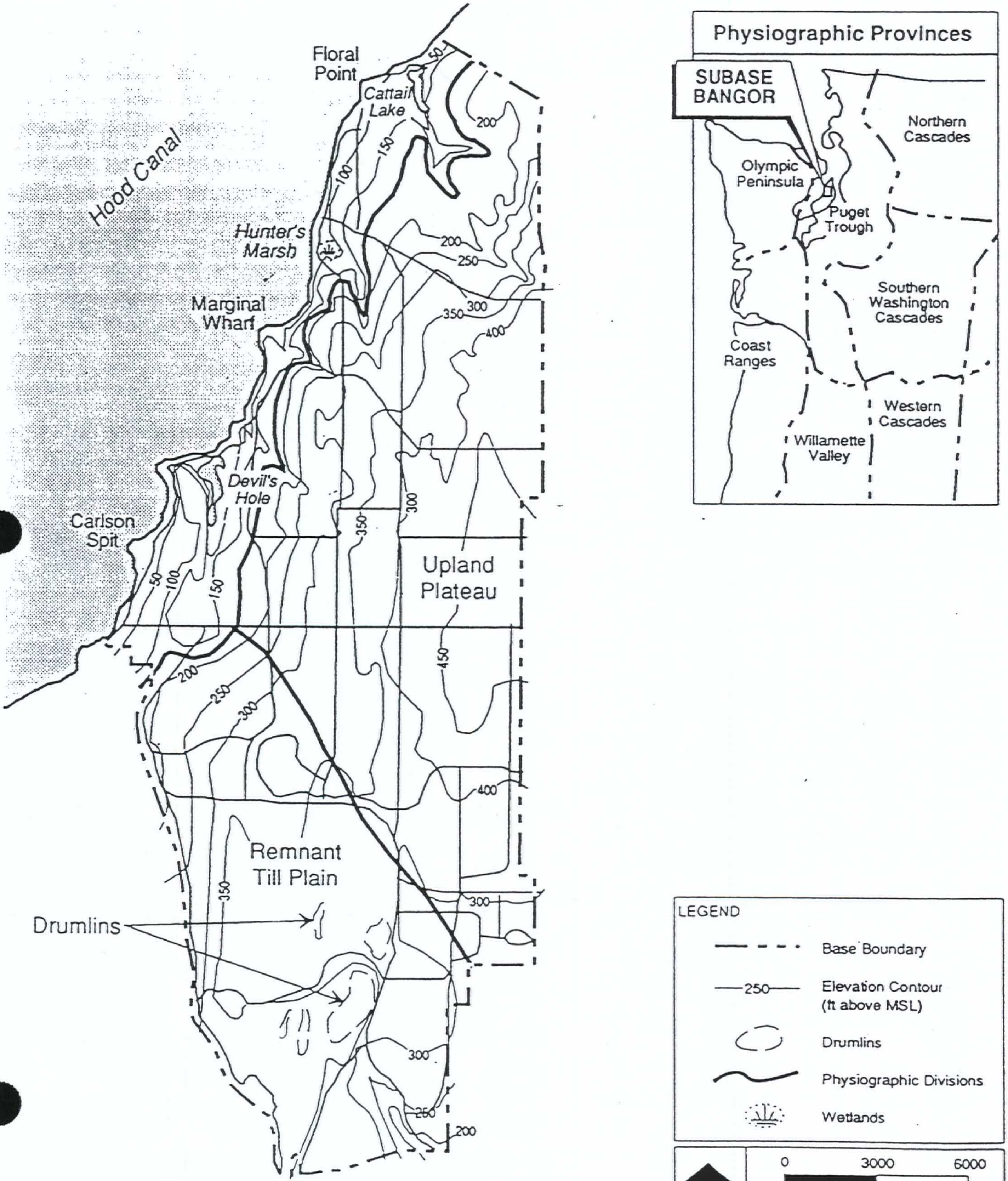
Subase Bangor can be divided into three physiographic areas:

- The upland plateau of the northern part of the base.
- The remnant glacial till plain at the southern end of the base.
- The estuarine and marine environments of Hood Canal.

Subase Bangor rises from sea level to an upland plateau that ranges in elevation from 300 to 500 feet. The western margin of the upland plateau in the northern part of the base is cut by a series of short, straight post-glacial drainages that discharge into Hood Canal. The southern part of the base is a preserved till plain, marked by a number of north-south trending drumlins. (A drumlin is a long, narrow or oval, smoothly rounded hill of unstratified glacial drift.) See Figure 3-7.

Most of Hood Canal has depths greater than 160 feet. Depths along the axis of Hood Canal west of Subase Bangor range from 180 to 380 feet. The 160-foot depth contour lies less than half a nautical mile from the Subase Bangor shoreline, indicating the steepness of the near shore slope.

Figure 3-7
Physiographic Setting of Subase Bangor



The Puget Sound Lowland is a broad structural trough filled with unconsolidated sediments of Miocene to Recent age overlying thousands of feet of early-Tertiary volcanic rocks (primarily basalt). Several major continental ice sheets advanced and retreated across the region during the Quaternary period (0 to 2 million years ago), repeatedly scouring and depositing a complex sequence of glacial and interglacial sediments. The last of these episodes is called the Fraser glaciation. It consisted of multiple minor pulses of ice advance of which the Vashon Stade was the most extensive and during which many of the water bearing strata within the area were deposited. Vashon glacial ice covered the area from approximately 15,000 to 13,500 years ago.

Key aquifers in glacial terrain are typically composed of sands and gravels deposited by streams and rivers of melt water flowing out in front of and to the sides of the glacier as it advances and recedes from the landscape ("outwash"). Also included is glacial till (material scoured, deposited, and compressed by the ice itself) which ranges in size from minute clay and rock flour particles to boulders. Such poorly sorted and over-consolidated deposits tend to impede ground water flow. Typical interglacial strata also include lake and stream deposits and organic-rich peats.

Six stratigraphic units are of particular significance in the hydrogeologic system at Subase Bangor. Their general characteristics are described below. Local outcrop areas of the stratigraphic units, as they occur at Subase Bangor, are shown on the surficial geologic map in Figure 3-8 and in cross section in Figure 3-9.

From youngest to oldest, the six stratigraphic units are:

- **Vashon Recessional Outwash** (Qvr) is a thin, discontinuous veneer of interbedded sand and gravel deposited by melt water from the receding glacier. The deposits are mainly large north-south trending outwash channels. Localized perched aquifers, situated in the depressions cut into the upper surface of the less permeable Vashon Till, provide small quantities of ground water.

- **Vashon Till** (Qvt) is a lodgment till made of a dense, hard, unsorted sequence of sediments ranging in thickness from a few feet to over 50 feet. It consists of variably sized gravel and boulders in a matrix of clay, silt, and sand deposited at the base of a glacier. The overall dense, compact nature of the till hinders ground water flow, making it one of the primary aquitards in the area. It serves as a low permeability base for perched aquifers and the upper boundary for confined ground water zones.

- **Vashon Advance Outwash** (Qva) consists primarily of coarse sands and gravels beneath the Vashon Till. A typical sequence consists of poorly sorted gravels at the top grading down to well-sorted, stratified sands and gravels with localized lenses of lacustrine clay. ("Lacustrine" means formed at the bottom of or along the shore of a lake.) This unit is highly permeable and may yield large quantities of water where it extends below the regional water table.

- The **Kitsap Formation** (Qk) consists of laminated silt and clay with an occasional layer of sand and gravel deposited in an interglacial lacustrine environment. The maximum thickness reaches 150 feet, with the top of the unit normally below sea level. An unnamed gravel is commonly associated with the top of the Kitsap Formation. The gravel unit consists of iron-stained, poorly bedded, fine to cobble gravels derived from the Olympic Mountains to the west and reworked granite pebbles from older glacial tills. The Kitsap Formation and the unnamed gravel yield small supplies of ground water.

- The **Older Sand and Gravel** (Qos) incorporates the Salmon Springs Drift and pre-Salmon Springs deposits which are undifferentiated. The Salmon Springs Drift consists of inter-bedded coarse gravels and sands deposited in a fluvial environment with local occurrences of glacial till. Pre-Salmon Springs deposits, undifferentiated, include both glacial and non glacial, fine-grained sands, silts, and clays. The top of these sediments occurs near sea level while the base has seldom been encountered. The combined thickness is believed to be over 200 feet. The coarser-grained Salmon Springs Drift is capable of supplying large quantities of artesian ground water. It is the most important ground water unit on the Kitsap Peninsula.

- **Tertiary Volcanic Bedrock** underlies these deposits and is predominantly basalt. The total thickness of these rocks is not known but exceeds 7,000 feet. The dense and extremely impermeable character of these rocks renders them unimportant as aquifers.

Figure 3-8
Surfical Geology of Subase Bangor

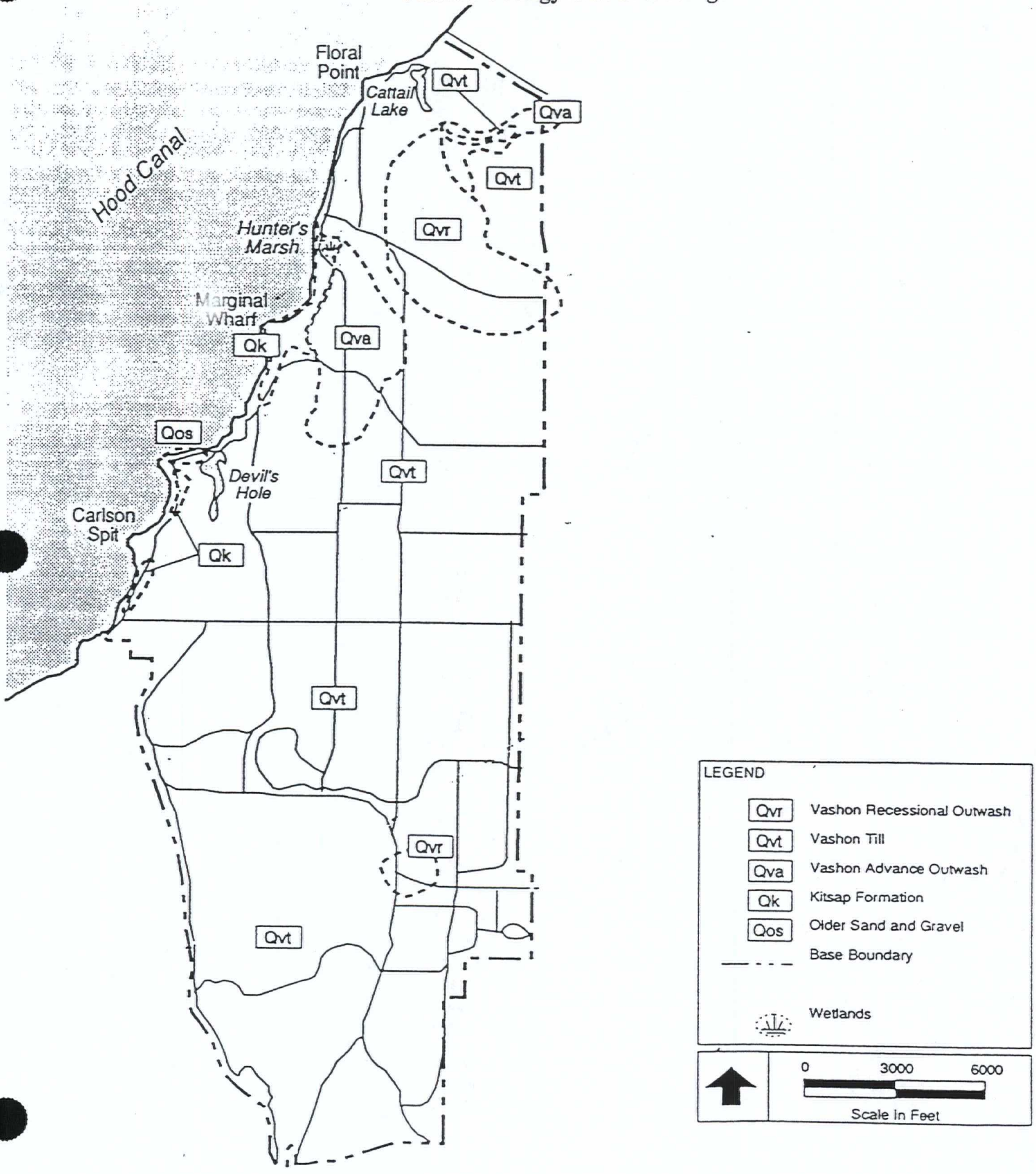
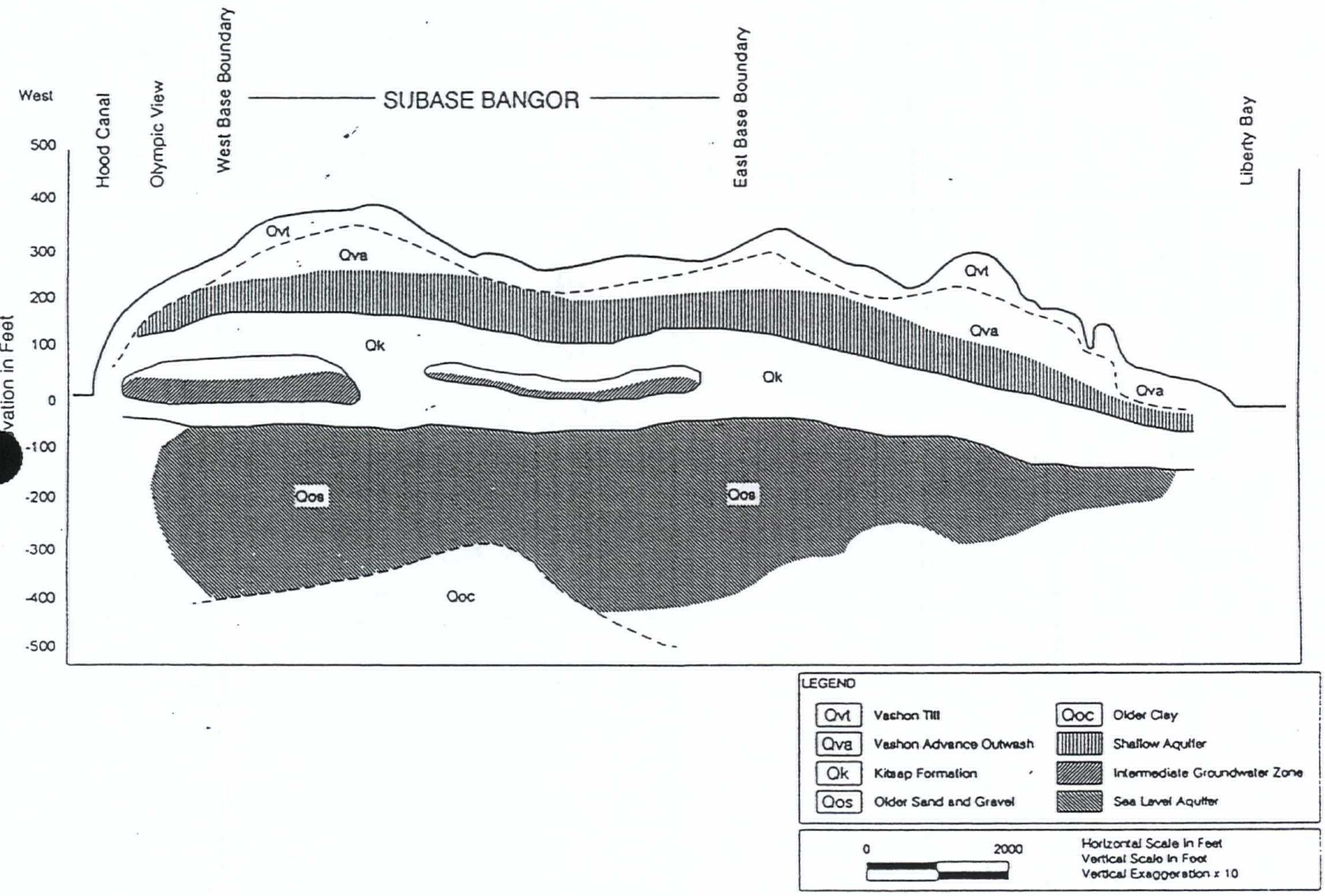


Figure 3-9
Geological Cross Section of Subase Bangor
Southern Section



3.3.3.2 **Soils** (References 1 and 3)

Kitsap County has four basic soil types:

- Soils underlain by cemented hardpan or bedrock substrate (Alderwood, Harstine, Sinclair, Edmonds, and Melbourne series).
- Soils with permeable, distinctly stratified substrata (Everett, Indianola, and Kitsap series).
- Organic soils represented by small, widely scattered areas of Greenwood, Mukilteo, Rifle, and Spalding peats and muck.
- Soils having little or no agricultural or building potential. Typical land forms include rough mountainous land, steep broken land, coastal beaches, and tidal marshes.

The most common surface soil in the northern section of the base is the Alderwood series - a very gravelly sandy loam with a percolation rate between 2.0 and 6.0 inches/hour. The depth to the hardpan ranges from 20 to 40 inches.

3.3.3.3 **Ground Water Sources and Uses** (References 1, 2 and 3)

Subase Bangor has four distinct superimposed aquifer systems. In order of increasing depth they are the Perched Aquifer, Semi-Perched Aquifer, Sea Level Aquifer, and Deep Aquifer. Contaminants, if present, could enter the Perched Aquifer through direct recharge from precipitation, and possibly the lower aquifers via leakage through overlying layers. The Perched and Semi-Perched Aquifers are used for potable water supplies in areas adjacent to Subase Bangor. The base obtains its water supply from the Sea Level Aquifer.

The Perched Aquifer and Semi-Perched Aquifer are identified in Figure 3-9 as the Shallow Aquifer and the Intermediate Groundwater Zone, respectively.

Beneath the base, the average thickness of the Perched Aquifer is approximately 70 feet. The saturated zone extends from approximately 130 feet to 200 feet below the surface. The Perched Aquifer appears to be a semi-confined system on a regional basis. For Subase Bangor the gradient of the Perched Aquifer is very flat (less than 6 inches in one-half mile). At Floral Point, and by inference for the whole near shoreline area, the Perched Aquifer flows parallel to topography outward into Hood Canal. Flow directions for deeper aquifers below the base are not known.

The Sea Level Aquifer occurs at elevations ranging from slightly above mean sea level to approximately 300 feet below mean sea level. The aquifer thickness ranges from a few feet to more than 300 feet. The confining aquitard ranges in thickness from a few feet to more than 200 feet. The piezometric surface of the sea level aquifer is above the top of the aquifer and, in lowland areas, the wells are flowing artesian.

The Sea Level Aquifer and, to a lesser extent, the Deep Aquifer are influenced by tidal fluctuations in Hood Canal. Sea water is in direct contact with the aquifers at points where submarine springs exist; however, the primary mechanism of tidal influence is the weight of the water transmitted through overlying formations. Compression of the aquifer causes the potentiometric surface to rise and fall with the tide.

Local precipitation is the primary source of water recharging the aquifers. Most of the precipitation occurs during the winter months of November through April. Precipitation and subsequent infiltration recharges the Perched Aquifer by downward percolation through the till. Regionally, the recharge to the intermediate ground water zones is by flow from the Perched Aquifer as indicated by downward vertical gradients.

The chemical quality of most ground water throughout the region is good to excellent. The relatively high annual precipitation rate (47 inches per year) results in low dissolved solids in the ground water, typically less than 150 milligrams per liter (mg/L). However, shallow wells very near the shoreline may have high chloride concentrations because of saltwater intrusion.

Water Supply

Three Sea Level Aquifer wells on the base provide all of Subase Bangor's drinking water. The three wells are on Hawkbill Road (grid N-6 on Figure 3-4). In addition there is a well in the Strategic Weapons Facility Pacific production area (Figure 3-4, grid Y-5) which is not in use, and one well near Fire Station #1 on Silversides Road (nonchlorinated well) which is used for irrigation (Figure 3-4, grid DD-10). Subase Bangor's drinking water wells supply water to approximately 13,000 people, including residents, employees, and Fleet personnel.

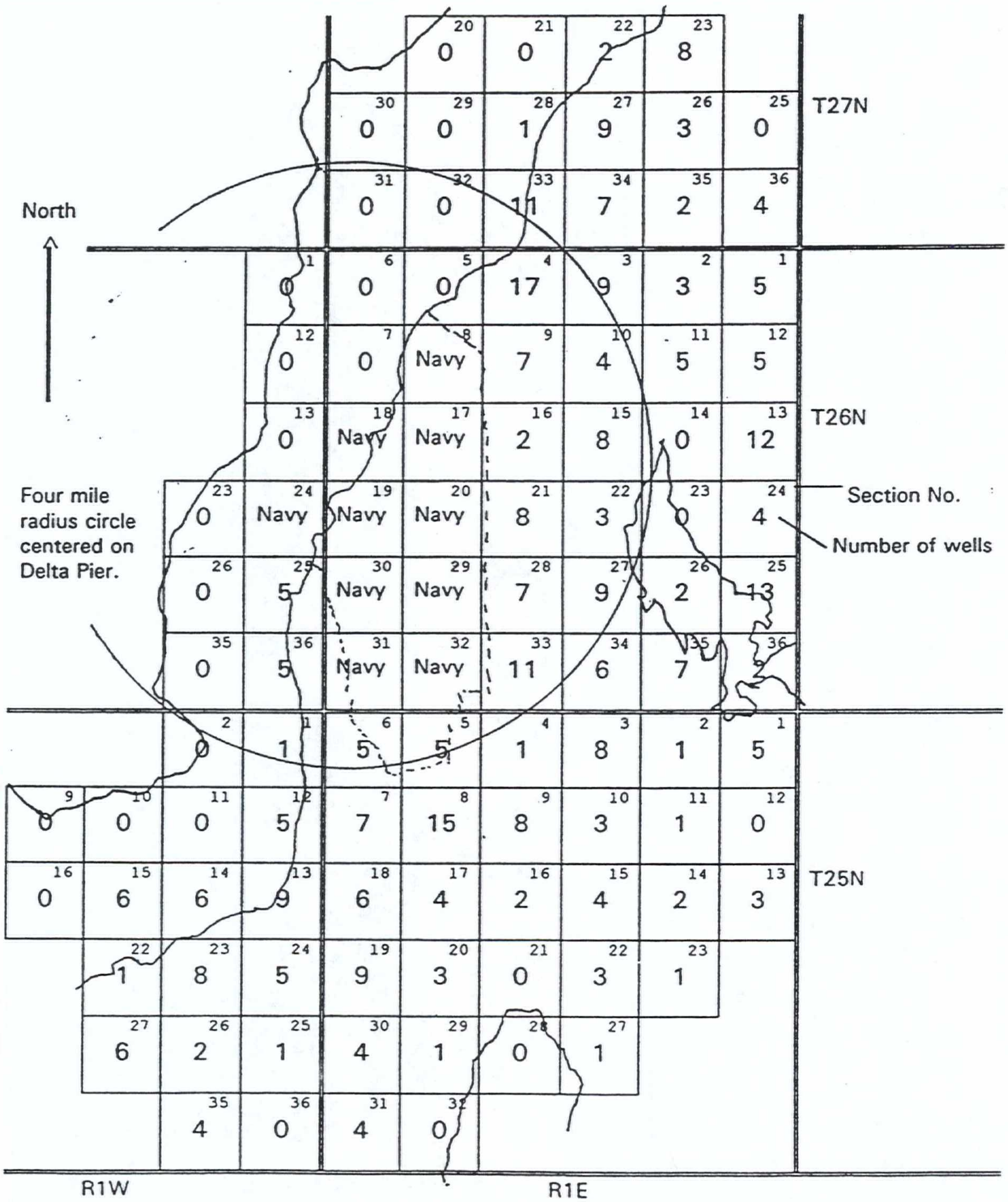
Subase Bangor formerly supplied potable water to one off base user - the Clear Creek School. The function of supplying potable water to Clear Creek School was taken over by the Silverdale Water District in early 1996.

There are numerous wells near the base: Kitsap County Public Utility District #1 has a potable water well in Vinland, the Silverdale Water District has a potable well near the southeastern portion of the base, and the community of Olympic View has two wells.

Figure 3-10 (Reference 4) shows the number of drinking water systems (i.e., wells) in each township section within four miles of Subase Bangor in Kitsap County. There are a total of 368 wells represented in Figure 3-10. One-third are within four miles of Delta Pier.

Figure 3-10

Drinking Water Systems by Section
Within Four Miles of Subase Bangor, East of Hood Canal



Legend: Navy = Subase Bangor

3.3.3.4 **Surface Water Sources and Uses** (References 1 and 2)

The region's typical lowland type streams and creeks have moderate gradients. The watersheds of the west half of Kitsap Peninsula drain into Hood Canal. Those on the east half of Kitsap Peninsula drain into Puget Sound. The highest flows are from November to February, and the lowest flows are during August and September. The streams are not large enough to pose significant flood hazards, but flooding of the low-lying areas adjacent to these streams does occur during extraordinarily high tides or wave action.

Surface drainage provides a primary link between the terrestrial and marine ecosystems that make up Subase Bangor; for example, Devil's Hole harbors immature salmon before they migrate into Hood Canal. Further, areas of extensive development and paving, such as the Controlled Industrial Facility, magnify the proportion and intensity of surface runoff from precipitation events.

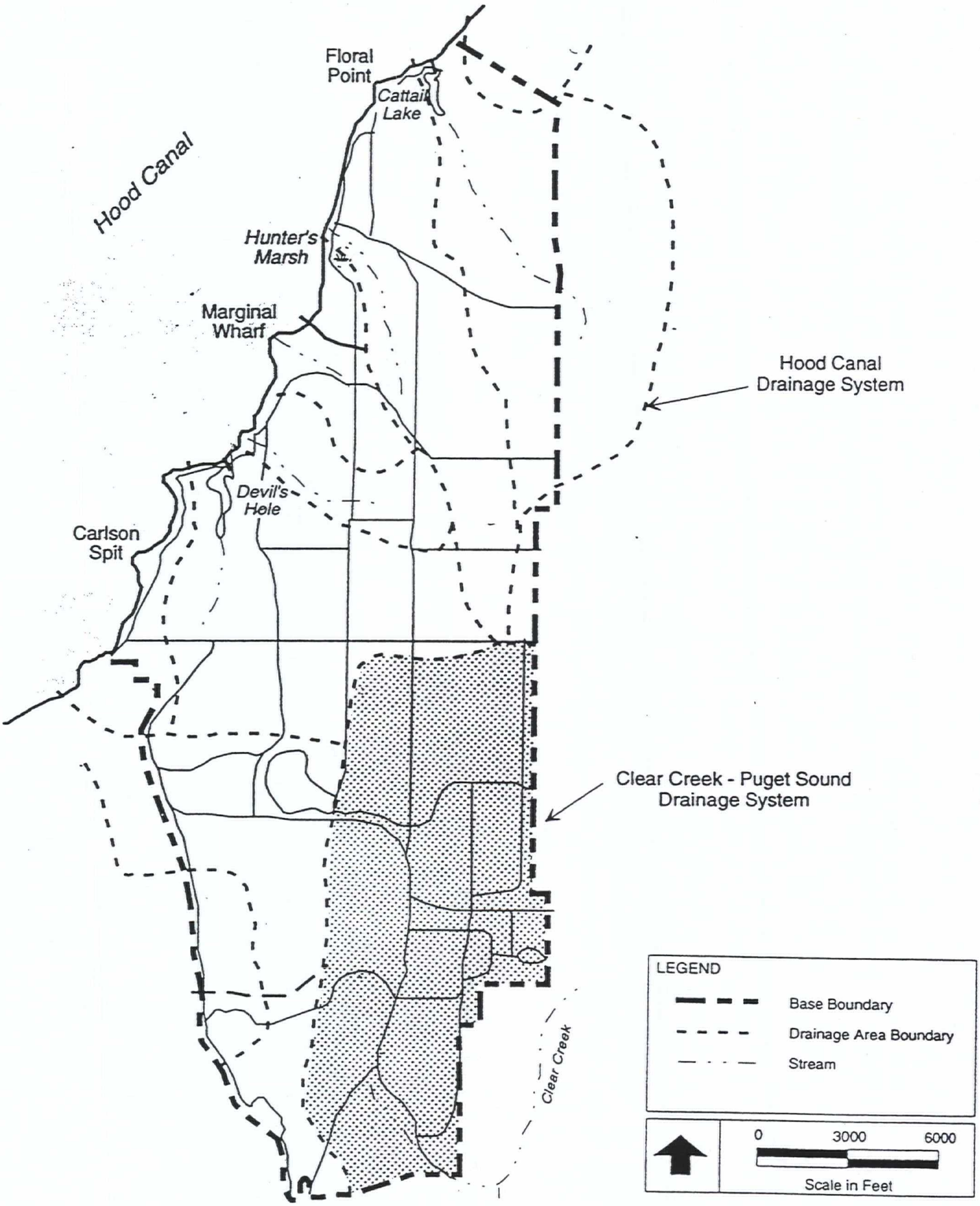
The Trident Support Site Environmental Impact Statement (U.S. Navy 1974) identified 15 small streams affected by Subase Bangor. Recorded stream flows range from 0.01 cubic feet per second (cfs) to 4 cfs derived from a 2.07 square mile drainage area for the stream passing through Devil's Hole. Drainage areas for the streams vary from 0.03 to 3.68 square miles.

Two drainage systems are recognized within Subase Bangor boundaries (Figure 3-11). The northern and western portions of the base feed the post-glacial drainages that discharge into Hood Canal. The southeastern corner of the base lies within the tributary system of Clear Creek, and drains into Dyes Inlet and Puget Sound. The surface sediments are coarse, unconsolidated, and highly permeable deposits into which surface water infiltrates rather than forming overland runoff.

Five short, straight, post-glacial drainages incise the margins of the upland plateau in the northern half of Subase Bangor (Figure 3-11). These drainages lack tributary systems and have a typical length of just over a mile. Their outlets into Hood Canal are spaced approximately one-half to one mile apart. Three of these drainages have been artificially dammed by shoreline road construction, creating Devil's Hole, Hunter's Marsh, and Cattail Lake. Overland flow from much of the western portion of Subase Bangor is routed to Hood Canal through a series of storm water outfalls.

Clear Creek and its tributaries form the best-developed drainage system in the area, draining the southeastern corner of Subase Bangor and covering approximately 750 acres. The west branch of Clear Creek (including the intermittent middle fork) originates on Subase Bangor. The east branch does not receive flow from the base. The combined Clear Creek drains into Dyes Inlet near the town of Silverdale.

Figure 3-11
Surface Water Hydrology



The most commercially important migratory fish species in Hood Canal is chum salmon, followed by chinook, coho, and pink salmon. While wild salmon stocks still occur in Hood Canal, the fishery is largely dependent on stocks produced by several hatcheries in the area. Commercially important resident groundfish species include English sole, rock sole, Pacific cod, surfperch, and dogfish. There are Pacific herring spawning grounds in areas of north and south Hood Canal.

Intertidal and subtidal shellfish populations in Hood Canal also support significant commercial and recreational fisheries. Predominant species are oysters, geoducks, Dungeness crab, shrimp, horse clams, butter clams, and Manila littleneck clams.

Subase Bangor's freshwater wetlands are sensitive environments. They cover about 460 acres and include three major wetlands: Devil's Hole, Cattail Lake, and Hunter's Marsh.

Washington State uses a four-tier wetlands rating system with Category I as the highest ranking. Devil's Hole (Category I) is a man-made lake located south of Delta Pier. Its 22 acres provide habitat for released salmon to mature before they migrate into Hood Canal.

Cattail Lake (Category II) is a man-made lake located southeast of the Magnetic Silencing Facility. Its 12 acres provide habitat for the three-spine stickle-back, freshwater sculpin, German brown trout, brook trout, and large mouth bass. A beaver family inhabits the stream draining into the lake.

Hunter's Marsh (Category II) is east of the Explosives Handling Wharf. Its 3 acres support a large population of spiders, insects, tree frogs, and waterfowl.

Cattail Lake and Devil's Hole have supported reproducing pairs of osprey since the early 1980's. Additional sensitive environments include forested areas, eel grass beds, and Great Blue Heron rookeries.

Because Hood Canal is saline it is not used for drinking water. There are no water systems with surface water intakes within Subase Bangor. The base includes almost all of the Hood Canal Drainage System (See Figure 3-11). The Silverdale Water District, south and southeast of the base, does not use surface water.

Figure 3-12, Surface Waters With Domestic Water Rights, lists by township-range all named surface waters with domestic water rights within the 15 mile target distance limit. In most cases the listed surface waters are used by only a few (one to three) households. The 15 mile target distance limit also includes unnamed streams, springs, and ponds.

Figure 3-12
Surface Waters With Domestic Water Rights

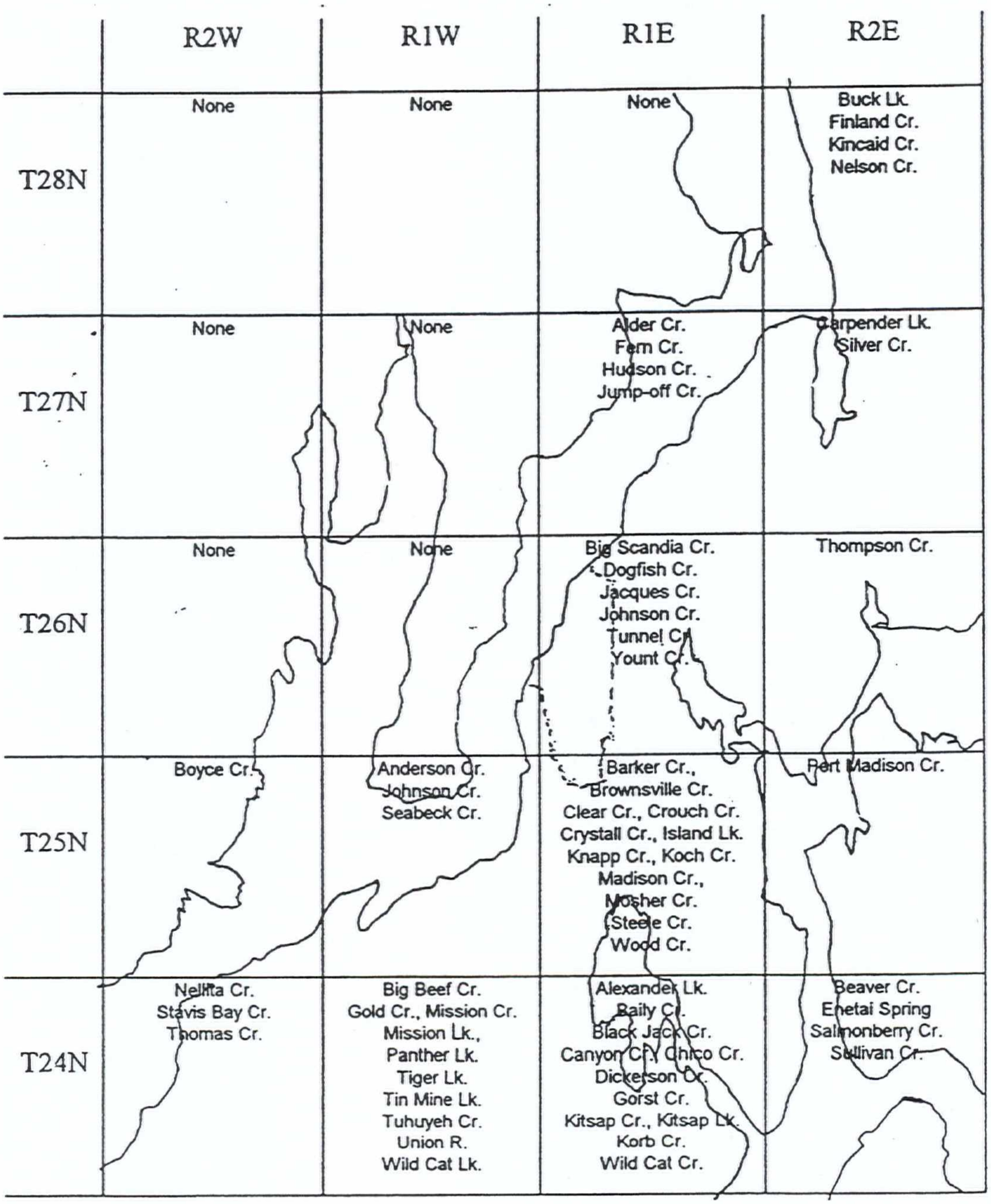
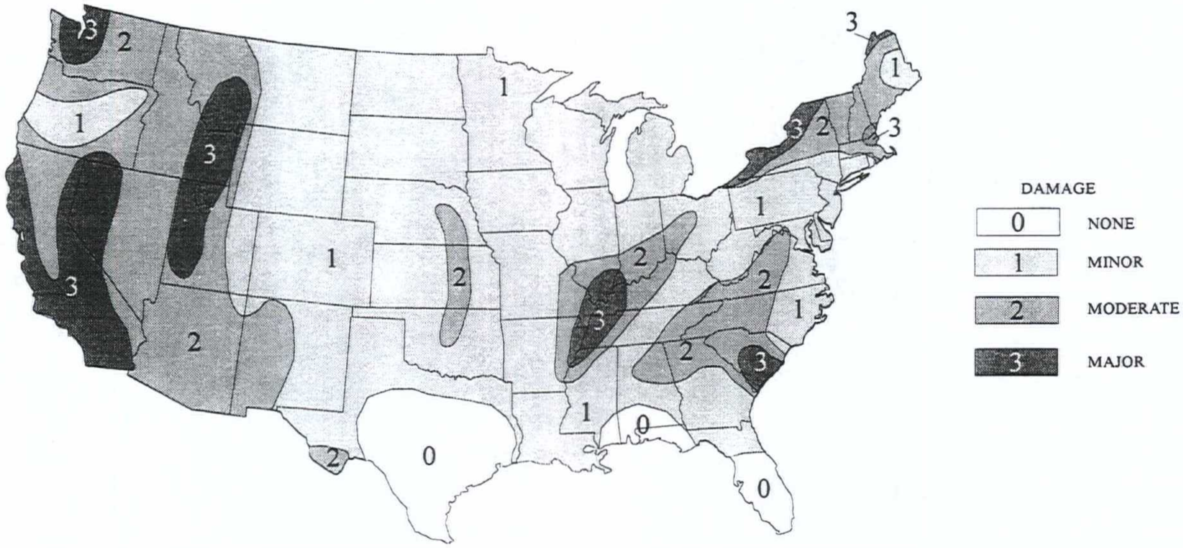


Figure 3-12 is based on a computer listing of recorded water rights compiled by the Washington State Department of Ecology, Northwest Regional Office, dated 4 May 1995.

3.3.3.8 **Seismology**

Seismic risk maps published by the U. S. Coast and Geodetic Survey place Kitsap County and Subase Bangor in risk zone 3, indicating an expectancy of major destructive earthquakes. There have been approximately 200 earthquakes since 1840, but there is no known surface faulting. The most recent earthquakes of high magnitude in the region were near Olympia in 1949 (7.1 on the Richter scale) and near Seattle in 1965 (6.5 on the Richter scale). Two known fault traces have been identified in the county: the Kingston-Bothell trace in the northern portion of the county and the Seattle-Bremerton trace located a few miles north of Bremerton.

Figure 3-13
Seismic Risk Map for Conterminous U.S.



The map divides the U. S. into four zones: Zone 0, areas with no reasonable expectancy of earthquake damage; Zone 1, expected minor damage; Zone 2, expected moderate damage; and Zone 3, where major destructive earthquakes may occur.

Reference: Robert J. Foster, "Physical Geology," Charles E. Merrill Publishing Company, Second Edition, 1975

3.3.4 **Climatology** (References 2 and 3)

Because of its proximity to the Pacific Ocean and the influences of Puget Sound, the Kitsap Peninsula has a maritime climate, with generally cool, dry summers and mild, wet winters. Winds from the south and southwest generally bring rain, whereas winds from the north and northwest bring clear weather. Occasionally during winter, cold air flowing south from Canada brings subfreezing temperatures.

The average summer temperature is between 70° and 80°F during the day and 50° to 60°F at night. Temperatures during winter range from 40° to 50°F during the day and 30° to 40°F at night. Temperatures below 0°F or above 100°F seldom occur.

The Olympic Mountains to the west form a barrier against cyclonic storms. Moving eastward under the prevailing influences of western winds and storm centers, the warm moisture-laden winds from the Pacific Ocean are cooled by their ascent of the western slopes of the Olympic mountains and subsequently release heavy rainfall. Winds entering through valleys to the south carry moisture into the Puget Sound Basin and deposit precipitation in decreasing amounts as they move eastward toward the Cascade Mountains.

Subase Bangor, which is located in the northern part of the Kitsap Peninsula, is situated in the rain shadow of the Olympic Mountains and thus receives considerably less rainfall than the southern portion of the peninsula. Subase Bangor receives approximately 47 inches of precipitation annually, according to the 40-year mean from the National Oceanic Atmospheric Administration (NOAA), Bremerton station. Total annual snowfall is approximately 16 inches.

The area's prevailing winds are generally from the south or south-southwest with the exception of September, at which time the wind is generally from the north. During the winter season, high winds attain velocities ranging from 25 to 45 miles an hour. In the summer, the average wind velocity is lower and the number of windy days also decreases.

Five to eight days a month are clear or partly cloudy in the winter. In the summer, clear or cloudy days increase to about 20 per month. Fog occurs an average of 10 percent of the time, but is as high as 20 percent in October and November. Relative humidity ranges from 75 to 85 percent during the day and up to 85 percent at night.

According to the Federal Emergency Management Agency (FEMA), lands at or above an elevation of 10 feet above mean sea level are considered to be above the 100-year flood plain. Except for the Hood Canal beach and low lying areas adjacent to streams where they enter Hood Canal, all Subase Bangor elevations are greater than 10 feet above mean sea level.

4.0 Description of Operations

4.1 Background on Navy Organizational Activities

4.1.1 Naval Facilities Engineering Command (NAVFAC)

NAVFAC is responsible for taking the lead in negotiating Federal Facilities Agreements (FFAs) with EPA regional offices and states.

4.1.2 Naval Nuclear Propulsion Program

The Naval Nuclear Propulsion Program is a joint Department of Energy (DOE)/ Department of the Navy program comprised of military and civilian personnel who design, build, operate, maintain, and oversee operation of Naval nuclear-powered ships and associated support facilities. The Program has a broad reach, maintaining responsibility for all aspects of Naval nuclear propulsion plants (including control of radiation and radioactivity) from cradle to grave. It is completely separate from the rest of the Navy and DOE activities that deal with radioactivity. Program responsibilities are delineated in Presidential Executive Order 12344 of February 1, 1982, and enacted as permanent law by Public Law 98-525 of October 19, 1984 (42 U.S.C. 7158). Program elements include:

- The Navy's nuclear-powered warships;
- Research and development laboratories;
- Contractors responsible for the design, procurement, and construction of propulsion plant equipment;
- Shipyards that construct, overhaul, and service the propulsion plants of nuclear-powered vessels;
- Navy nuclear support facilities and tenders;
- Nuclear power schools and Naval Reactors training facilities; and
- The Naval Nuclear Propulsion Program headquarters organization and field offices.

Admiral H. G. Rickover developed the Naval Nuclear Propulsion Program at the end of World War II, with a commitment to technical excellence and an organization staffed by experienced professionals dedicated to designing, building, and operating Naval nuclear propulsion plants safely and in a manner that protects people and the environment. Executive Order 12344 and Public Law 98-525 capture the concepts and principles central to the Program's accomplishments.

Dealing with radioactive materials and ionizing radiation safely and responsibly has been an integral part of the NNPP from the beginning. It was recognized that the usefulness of nuclear-powered warships would be seriously hampered if operational restrictions were necessary because of radiological concerns. Therefore, the reactor plants were designed and continue to be operated such that the radiological impact on people and the environment is minimized. The NNPP established limits for releases to the environment which were well below limits applied to operation of commercial nuclear power plants (see Section 5.1.1.1). NNPP policy has been to control radioactivity such that radiological environmental impact is insignificant compared to natural radioactivity levels in the environment. From the start of the Naval Nuclear Propulsion Program, the policy has been to reduce to the minimum practicable the amounts of radioactivity released into the environment.

4.2 Radioactivity from Naval Nuclear Propulsion Plants

Naval nuclear propulsion plants differ from commercial power generating reactors in several important ways with respect to potential environmental impact. They are considerably smaller both in physical size and power output. To assure safe operation in close proximity to operating crews under possible high shock loading of battle conditions, the reactor plants are much more durable. Leakage of fission products into the cooling system, or leakage of the cooling system, are not compatible with ship operation and are not tolerated. Over 40 years experience with Naval nuclear propulsion plants has shown that fission products are contained in the fuel elements. This characteristic significantly reduces the potential for radiological environmental impact.

In the shipboard reactors, pressurized (non-boiling) water circulating through the reactor core picks up the heat of nuclear reaction. The reactor cooling water circulates through a closed piping system to heat exchangers which transfer the heat to water in a secondary steam system isolated from the primary cooling water. The secondary system water is turned into steam, which is then used as the source of power for the propulsion plant as well as for auxiliary machinery. Releases from the shipboard reactors occur primarily when reactor cooling water expands as a result of being heated up to operating temperature; this coolant passes through a purification system ion exchange resin bed prior to being transferred from the ship.

While fission products produced in the fuel, including iodine and the fission gases krypton and xenon, are retained within the fuel elements, some trace quantities of naturally occurring uranium impurities in the surface of reactor structural materials release small amounts of fission products to the reactor coolant. The concentrations of fission products and the volumes of reactor coolant released are so low, however, that the total radioactivity attributed to long-lived fission product radionuclides comprises only a small fraction of the total long-lived gamma radioactivity releases discussed elsewhere in this section of this report.

The primary mechanism by which environmental releases of NNPP radioactivity occur include: (1) inadvertent releases of small volumes of liquids (or pre-1972 historical releases) to the harbor, as discussed in Section 5.1.1; (2) inadvertent releases of small amounts of liquid or solid material (or, very rarely, gases), as listed in Section 5.1.3; (3) the particulate output from HEPA-filtered air exhausts at work areas, as discussed in Section 5.1.2; and (4) the release of trace quantities of fission product gasses and carbon-14 gaseous products from primary coolant which has been depressurized (including that which is removed from ships for processing into controlled pure water, as discussed in Section 5.1.1.1). Note that ships are prohibited from discharging reactor cooling water overboard in the vicinity of shore; hence, shipboard reactor operations are not considered a significant potential source of environmental contamination.

4.2.1 **Cobalt-60**

The principal source of radioactivity in liquid effluents or encountered during maintenance work is trace amounts of corrosion and wear products from reactor plant metal surfaces in contact with reactor cooling water. Radionuclides with half-lives of approximately one day or greater in these corrosion and wear products include tungsten-187, chromium-51, hafnium-181, iron-59, iron-55, nickel-63, niobium-95, zirconium-95, tantalum-182, manganese-54, cobalt-58, and cobalt-60. The most predominant of these is cobalt-60, which has a 5.3 year half-life. Cobalt-60 also has the most restrictive concentration limits, as listed in Reference 5. Therefore, cobalt-60 is the primary radionuclide of interest for Naval nuclear propulsion plants.

(Half-life is the time required for a radioactive material to decay to one-half its starting activity level. For example, 30 pCi/g of cobalt-60 would be 15 pCi/g after 5.3 years, 7.5 pCi/g after 10.6 years, 3.75 pCi/g after 15.9 years, etc.)

4.2.2 **Tritium**

Small amounts of tritium are formed in reactor coolant systems as a result of neutron interaction with the approximately 0.015 percent of hydrogen in water that is naturally occurring deuterium, and as a result of certain other nuclear reactions. Although tritium has a 12.3 year half-life, the radiation produced is of such low energy (weak beta; no gamma) that the Reference 5 radioactivity concentration limit for tritium is at least one hundred times higher than for cobalt-60. This tritium is in the oxide form (i.e., water) and is chemically indistinguishable from normal water; therefore, it does not concentrate in marine life or collect on sediment as do other radionuclides.

Tritium is naturally present in the environment because it is generated by cosmic radiation in the upper atmosphere. Reference 6 estimates the natural production rate of tritium would produce a global equilibrium inventory of between 28 million and 70 million curies. Table 3.3 of Reference 6 shows that 65 percent of the global inventory occurs in oceanic waters. These values yield an oceanic inventory of about 18 million to 45 million curies. Because of this naturally occurring tritium, much larger releases of tritium than are conceivable from Naval nuclear reactors would be required to make a measurable change in the background tritium concentration.

The total amount of tritium released annually from all U.S. Naval nuclear-powered ships and their supporting tenders, bases, and shipyards has been less than 200 curies. Most of this has been into the ocean greater than twelve miles from shore. The total tritium released annually from the entire nuclear Navy is less than single electrical generating nuclear power stations typically release each year. Total tritium released annually into harbors within twelve miles of shore is less than one curie. Appendix B of Reference 6 reports an estimated dose due to natural tritium in the environment of between 1.0 μrem/yr and 1.5 μrem/yr. In comparison to the millions of curies naturally occurring in the oceans, the 200 curies of tritium per year released from nuclear ships is insignificant to both the global inventory and to the annual dose due to the environmental tritium. Therefore, tritium has not been combined with the data on other radionuclides in other sections of this report.

4.2.3 **Carbon-14**

Carbon-14 is also formed in small quantities in reactor coolant systems as a result of neutron interactions with nitrogen and oxygen. This carbon is in the form of a gas, primarily methane and ethane, although some insoluble carbonates may be present; following reprocessing of reactor coolant (to make controlled pure water), it is possible some carbon-14 has been converted to carbon dioxide. Carbon-14 decays with a half-life of 5,730 years; however, only low energy beta radiation is emitted as a result of this decay process. As a result, the Reference 5 radioactivity concentration limit for carbon-14 in its chemical form in air is sixty times higher than for cobalt-60.

Carbon-14 occurs naturally in the environment. It is generated from cosmic radiation interactions with nitrogen and oxygen in the upper atmosphere and oxidized to form carbon dioxide. Appendix B of Reference 6 states that "weapons testing has essentially doubled the atmospheric inventory of carbon-14 present from natural sources." Carbon-14 is chemically indistinguishable from other isotopes of carbon. The carbon dioxide diffuses and convects throughout the atmosphere and enters the earth's carbon cycle (i.e., achieving equilibrium concentrations in all living organisms; this is what permits "carbon dating" of deceased organisms, since carbon-14 in dead matter decays and is not replenished).

The earth's carbon-14 inventory is estimated to be about two hundred and fifty million curies. The total amount of carbon-14 released annually from the operation of all U.S. Naval nuclear-powered ships and their supporting tenders, bases, and shipyards has been less than 100 curies, most of which is released at sea beyond twelve miles from shore. Since the inventory of naturally occurring carbon-14 is millions of curies, releases from Naval nuclear reactors do not result in a measurable change in the background concentration of carbon-14.

Typical annual releases of carbon-14 at Subase Bangor are about 1 curie per year, virtually all as a gas. This is much less than the approximately 7 curies per year discharged by the typical commercial nuclear power plant per Reference 7. These gaseous releases are dispersed in the atmosphere and are not concentrated in the environment. Calculations using the EPA COMPLY computer code indicate that the resulting dose is less than 1.0 mrem per year. Furthermore, a study around a large civilian nuclear power plant showed no measurable carbon-14 in downwind foliage (Reference 8). For these reasons, carbon-14 is not judged a remediation concern, and carbon-14 data has not been combined with the data on other radionuclides in other sections of this report.

4.3 **Type of Activities**

Navy facilities authorized to perform radioactive work associated with Naval nuclear propulsion plants perform a wide range of maintenance, repair, and upgrading activities. Some facilities also refuel reactor plants (not done at Subase Bangor). Refueling involves removal of spent fuel into special shipping containers and installation of new fuel. No work on or processing of fuel is performed at these facilities. Radioactive materials encountered during reactor plant work include reactor coolant that is processed and reused, reactor plant components (including removed and/or unusable components), tools and equipment used to perform the work, reusable (laundered) contamination control clothing, and contamination control waste products such as plastic bags, tape, plastic bottles, and impervious fabrics.

Trade skills required for reactor plant work are the same as for typical shipyard operations. Machinists, pipefitters, shipfitters, welders, sheet metal workers, electricians, painters, fabric workers, and riggers perform the work. Work is directed by engineers and monitored by inspectors and radiological control technicians. At Subase Bangor, the majority of the NNPP-related work is performed by active duty military personnel assigned to the Trident Refit Facility (TRF). The primary differences from other work are the extremely high quality standards and the interaction with radiation and radioactive materials. For example, it is common to train personnel on uncontaminated mockups prior to performing work on contaminated systems, to minimize exposure and help preclude errors.

Qualified Navy crews also operate the reactor plants for limited training and to test the plants following maintenance.

4.4 Control of Radioactivity

A major objective in the performance of Naval nuclear propulsion plant work is avoiding the potential for releases of low level radioactivity into the environment. From the beginning of the NNPP, radiological work has been performed under strict controls to preclude the spread of contamination, by containing radioactivity at the source to the smallest practicable area or volume. Facilities where work on radioactive materials is performed are specifically designed to contain radioactivity. Design criteria include impervious walls, easily decontaminated surfaces, absence of floor drains, and ventilation systems with High Efficiency Particulate Air (HEPA) filtered exhausts to maintain a negative pressure in work areas. The HEPA filters are 99.97% efficient at removing 0.3 micron particles. The filtered exhausts are monitored with an Environmental Monitoring System; results of this monitoring are discussed in Section 5.

In addition, most work on radioactive materials is performed inside Contamination Containment Areas inside these facilities with all the same features as the building. This provides double isolation of radioactivity from the environment. In the event of a loss of containment (e.g., a liquid spill or a puncture in a containment), immediate action is taken to isolate and correct the problem, and to sample/survey to verify complete recovery.

Radioactive material in storage areas is packaged to contain any loose radioactive contamination and is surveyed prior to transfer by radiological control personnel to ensure the outside of the packaging is not contaminated. Radioactive material storage areas are surveyed for loose radioactive contamination periodically by radiological control personnel.

The work area of the Controlled Industrial Facility (CIF) is designated as a Radiologically Controlled Area. It is physically separated from the office area of the building. Access to the CIF is restricted. Access to the Radiologically Controlled Area for both personnel and material is via a control point manned by radiological control personnel. Personnel and material exiting the

Radiologically Controlled Area are surveyed for radioactive contamination with portal monitors or beta-gamma friskers.

All areas within a Radiologically Controlled Area are maintained less than 450 pCi/100 cm^2 (by swipe analysis), except for those areas designated and specially controlled as Controlled Surface Contamination Areas. Controlled Surface Contamination Areas are maintained at or near 450 pCi/100 cm^2 even during work on contaminated items. Radiologically Controlled Areas and Controlled Surface Contamination Areas are surveyed frequently by radiological control personnel to ensure that radioactive contamination levels are held below NNPP limits.

A primary design criterion for Naval nuclear propulsion plants was minimal release of radioactivity during reactor operation to avoid the need for operational restrictions while in port. Therefore, there is no significant environmental impact from the small amount of reactor operation for reactor testing at Subase Bangor.

The NNPP controls radioactivity at the source by using the concept of total containment. This policy minimizes the spread of radioactive contamination to adjacent surfaces and to personnel. Engineered ventilation systems containing HEPA filters, drapes, glove bags, and tents are utilized to accomplish this goal. Any personnel, instructional, or equipment errors that result in even a minor spread of contamination halt the work until the cause is determined and corrective action is taken. This policy and its successful application allow most radiological work to be performed without personal protective clothing or respirators. In addition to permitting work to be accomplished more efficiently, the number and extent of radiological areas requiring release is minimized.

Radioactive materials are either maintained within controlled areas, or are attended or physically secured at all times. Movement of radioactive materials outside controlled areas requires a strict accountability system. All movements are verified by an individual other than the one performing the move.

Routine radiological surveys in and around facilities where work on radioactive materials is performed confirm that controls are effective. Corrective actions are taken immediately in the unusual event that surveys identify unexpected radioactivity. Inadvertent releases are cleaned up immediately (within hours if practicable), and a critique is held to identify and correct the cause of the problem. Detectable radioactivity in uncontrolled areas is not permitted.

The basic policies covering control of radioactivity have not been changed since the beginning of the NNPP. There has been continuous upgrading based on over 40 years of experience. An example of this is development of processing methods to make radioactive liquids reusable as reactor coolant. Other examples of upgrading include improved work facilities, development of improved contamination containment area designs, solid radioactive waste volume reduction, improved radiological analysis of environmental samples, and the extensive use of engineered ventilation systems. Upgraded monitoring methods have not detected problems with the basic control methods which have been used from the beginning of the Program.

4.5 **Regulatory Oversight**

NNPP radiological controls at Subase Bangor are overseen by Naval Nuclear Propulsion Program headquarters. As the NNPP's representative, nuclear-trained personnel on the Fleet Commander (CINCPACFLT) and Type Commander (COMSUBPAC) staffs performed annual on-site audits of all Subase Bangor nuclear work practices, including radiological controls, worker training, quality control, and compliance with work procedures and headquarters requirements. Similar on-site audits were occasionally performed by NNPP headquarters as overchecks. These on-site reviews were performed in support of the NNPP authorization for Subase Bangor handling of NNPP radiological materials. With the establishment of a Naval Regional Maintenance Depot (NRMD) at Subase in late 1996, management of NNPP radiological controls is now the responsibility of Puget Sound Naval Shipyard. PSNS work at Subase Bangor is overseen by NNPP headquarters, and is reviewed as part of the annual NNPP onsite audits of the shipyard.

Regulatory interface regarding mixed (radiological and hazardous) waste is addressed in Section 5.3.

5.0 **Policies and Results**

5.1 **Policies and Records Related to Environmental Release of Radioactivity**

5.1.1 **Liquid Discharges**

5.1.1.1 **Policy**

General

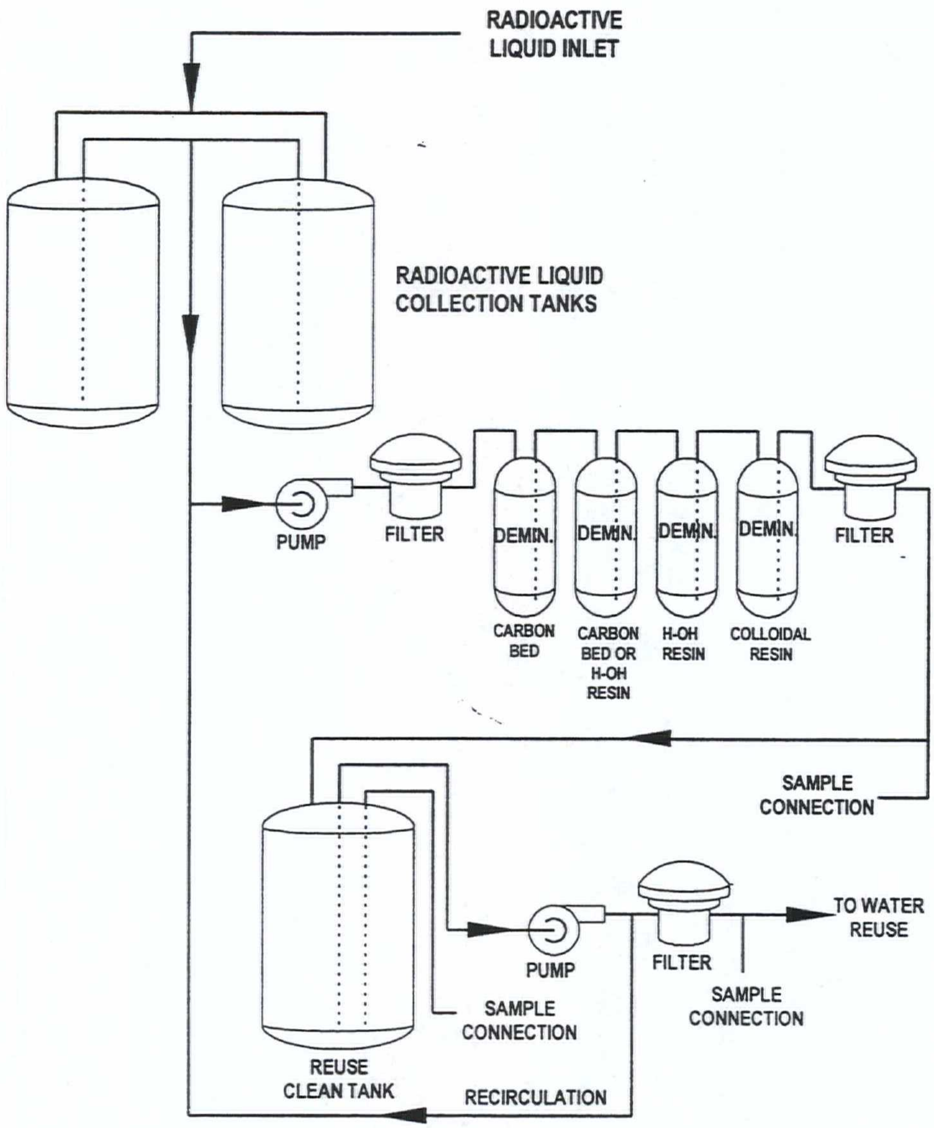
As stated in Reference 9, the policy of the NNPP is to minimize the amount of radioactivity released to the environment, particularly within twelve miles of shore (e.g., including into harbors). This policy is consistent with applicable recommendations issued by the Federal Radiation Council (incorporated into the Environmental Protection Agency in 1970), U.S. Nuclear Regulatory Commission, National Council on Radiation Protection and Measurements, International Commission on Radiological Protection, International Atomic Energy Agency, and National Academy of Sciences--National Research Council. To implement this policy of minimizing releases, the NNPP has issued standard instructions defining radioactive release limits and procedures to be used by U.S. Naval nuclear-powered ships and their support facilities.

The policies and procedures instituted by about 1972 remain in place through the present. The total amount of long-lived (half-life greater than one day) gamma radioactivity released into harbors and seas within twelve miles of shore by the entire Naval Nuclear Propulsion Program has been less than 0.002 curie during each of the last twenty-six years. This total is for releases from U.S. Naval nuclear-powered ships and from the supporting shipyards, tenders, and submarine bases, including releases at operating bases and home ports in the U.S. and overseas and all other U.S. and foreign ports which were visited by Naval nuclear-powered ships. This activity level is conservatively reported as if it consisted entirely of cobalt-60, which is the predominant long-lived gamma radionuclide and also has the most stringent concentration limits.

Processing and Reuse of Radioactive Liquids

Radioactive liquids at Subase Bangor are collected in special tanks designed for this purpose and processed through a processing system to remove most of the radioactivity (exclusive of tritium) prior to collection in a clean tank for reuse. Figure 5-1 shows a simplified block diagram of the liquid processing system which consists of particulate filters, activated carbon bed filters, mixed hydrogen hydroxyl resin, and colloid removal resin beds. This type of processing system has been developed and used successfully to produce high quality water containing very low radioactivity levels. The NNPP refers to this as "Controlled Pure Water" (CPW).

Figure 5-1
Simplified Diagram of Typical Radioactive Liquid Processing System



Even after processing to approximately 10^{-8} μCi/ml, reactor coolant is not discharged into Hood Canal. Rather, it is returned to ships. To put this CPW in perspective, the Safe Drinking Water Act of 1974 standards established in Title 40 Code of Federal Regulations Part 141 (40 CFR 141) specify that the annual dose equivalent to the total body or any internal organ shall not be greater than 4 millirem/year from man-made radionuclides in drinking water based on continuous consumption. If water containing cobalt-60 at a level of 3×10^{-6} μCi/ml were consumed continuously for a year, the total effective dose equivalent would equal 50 millirem. This value is derived from Reference 5. This means that if a person's total water intake for a year, including all water in fruit, meat, etc., were 100% CPW at the NNPP limit of 6×10^{-8} μCi/ml cobalt-60, the cobalt-60 would result in a total effective annual dose equivalent of 1 millirem per year (one-fourth the EPA limit). The dose due to tritium in the water would be about 100 millirem, but since this intake scenario is highly unrealistic, the potential dose to any person is actually very small. Release to the environment of such water would have negligible impact.

Policy Details

Standardized NNPP instructions concerning discharges of radioactive liquids from nuclear-powered ships were first issued in 1958. In 1960, all of the prior instructions were consolidated and incorporated into a technical manual for use by all submarine bases in their radiological control programs.

The basic criteria for release limits set in 1958 was that disposal of radioactive liquids should not increase the average concentrations of radionuclides in the surrounding environment by more than one-tenth of the maximum permissible concentrations for continuous exposure listed in National Bureau of Standards Handbook 52, Reference 10.

Measurements showed a dilution of over 100,000 for reactor coolant discharged from a ship. Credit for dilution was reduced to a factor of 1000 to be conservative. By setting the coolant discharge concentration limit at 100 times the Handbook 52 value for specific radionuclides listed, and taking credit for a 1000-fold dilution, the one-tenth criteria was met.

In January 1960, the NNPP release criteria was revised to be one-tenth of the limit of National Bureau of Standards Handbook 69, Reference 11. The Handbook 69 values were subsequently incorporated into Reference 5. 10 CFR 20 continues to serve as the commercial nuclear industry basis for radioactive effluents in air or water through the present. The standard instructions codified in 1965 for use by all NNPP activities were based on the limits of 10 CFR 20, to ensure consistency with commercial standards where practical.

Between 1958 and May 1961, shore activities were allowed to dilute radioactive liquids to less than 3×10^{-5} μCi/ml prior to discharge. In May 1961, the Program required that radioactive liquids be treated by filtration and ion exchangers to minimize the dilution required to attain the 3×10^{-5} μCi/ml limit. In December 1965, requirements were modified to prefer additional treatment to attain the allowable concentrations in lieu of dilution.

In addition to the concentration limits discussed above, other limits and conditions were required, including total activity per year, total activity per work shift, tidal conditions at the time of discharge, total gallons discharged, and proper authorizations. These NNPP limits and conditions were more conservative than any other agency's regulations at this time.

The tritium (hydrogen-3) concentration in both reactor coolant and controlled pure water is the same, at about 2×10^{-3} µCi/ml or less. This is below the 10 CFR 20 sanitary sewer release criteria for tritium which the Nuclear Regulatory Commission uses for sites it regulates. Any such water which entered Hood Canal would be rapidly diluted and become indistinguishable from background tritium levels, as discussed in Section 4.2.2. If any small volume spilled on land and went undetected, it would be quickly washed into Hood Canal (e.g., by rainwater, or possibly by entering the shallow ground water system which discharges into Hood Canal as discussed in Section 3.3.3.3). No environmental mechanism to concentrate this radionuclide exists.

During 1970, shore activities were directed to acquire the capability to collect, process, and reuse reactor cooling water. In June of 1972, the Program regulations directed that discharges of processed liquids could only be made with specific approval of Naval Nuclear Propulsion Program headquarters.

5.1.1.2 **Liquid Discharges and Records**

Subase Bangor has never intentionally discharged radioactive liquids to Hood Canal and has not requested permission to do so.

Data concerning volume and total radioactivity discharged at Subase Bangor were summed and the values reported annually to NNPP headquarters. These values are shown in Table 5-1.

As shown in Table 5-1, the highest annual activity discharged at Subase Bangor was <0.001 curie, which is less than the naturally occurring radioactivity in a cube of sea water 16 yards on a side (Reference 12). For the entire NNPP, annual discharges within 12 miles of land prior to 1973 ranged from 1 to 10 curies; total NNPP discharges (including at sea) have been 0.4 Ci/yr since about 1975 (less than 0.002 curie within 12 miles of land). Compared to the discharges from other nuclear programs and activities and to the millions of curies occurring naturally in the oceans, even the pre-1973 amount of radioactivity is small. Table 5-2 shows 1990 radioactivity discharges from commercial nuclear power plants, in comparison to the NNPP total within 12 miles of land. (Table 5-2 includes all radionuclides with a half-life of greater than 8 days.)

From 1973 through 1996, Puget Sound Naval Shipyard reported combined shipyard and Subase Bangor total annual discharges (i.e., inadvertent discharges to the harbor) of less than 1000 gallons and less than 0.001 curie. This volume primarily originates from disconnecting underwater joints between Subase collection facilities and nuclear submarines. These lines are blown down prior to disconnection, but some residual water remains at low points in hard piping. Since the disconnection is made by divers, there is no way to measure the amount of residual water in the hard piping connected to the ship. The 1000 gallons is a very conservative volume.

In most years, the volume actually released is much less than 1000 gallons. The "less than 0.001 curie" reported is based on a total discharge of 1000 gallons, and is also very conservative. These volumes do not include rare spills of controlled pure water, due to the very low levels of activity in such water as discussed above. These spills did not affect the "less than 0.001 curie" reported.

Table 5-1
Radioactive Liquid Waste Released to Hood Canal From Subase Bangor Due to NNPP Operations 1973 - 1996

Year	Volume (Thousand Gallons)	Activity (Curies)	Potential Tritium Released (Curies)
1996	<1	<0.001	<0.008
1995	<1	<0.001	<0.008
1994	<1	<0.001	<0.008
1993	<1	<0.001	<0.008
1992	<1	<0.001	<0.008
1991	<1	<0.001	<0.008
1990	<1	<0.001	<0.008
1989	<1	<0.001	<0.008
1988	<1	<0.001	<0.008
1987	<1	<0.001	<0.008
1986	<1	<0.001	<0.008
1985	<1	<0.001	<0.008
1984	<1	<0.001	<0.008
1983	<1	<0.001	<0.008
1982	<1	<0.001	<0.008
1981	<1	<0.001	<0.008
1980	<1	<0.001	<0.008
1979	<1	<0.001	<0.008
1978	<1	<0.001	<0.008
1977	<1	<0.001	<0.008
1976	<1	<0.001	<0.008
1975	<1	<0.001	<0.008
1974	<1	<0.001	<0.008
1973	<1	<0.001	<0.008

Notes:

a. Includes inadvertent releases. Activity is reported as cobalt-60 equivalent. Refer to Section 2.3 for a discussion of counting terminology. Carbon-14 is excluded. Potential tritium released values assume 0.002 μCi/ml tritium (effectively a worst case estimate for reactor coolant). For comparison, a typical commercial nuclear reactor plant releases several hundred curies of tritium in liquid effluents every year.

b. Table includes all unplanned discharges listed in Table 5-4.

Table 5-2

Environmental Releases (Curies) On Land or Within Territorial Waters Naval[1] vs. Civilian[2] Reactors

AIRBORNE

PEACH BOTTOM 2 & 3	11200	
OCONEE 1, 2 & 3	8840	
CRYSTAL RIVER 3	7310	
SEQUOYAH 1 & 2	6070	
WATERFORD 3	5730	
BIG ROCK POINT 1	5550	
VERMONT YANKEE 1	5070	
MONTICELLO	2960	
MILLSTONE 2	2890	
INDIAN POINT 1 & 2	2230	
SAN ONOFRE 1	1800	
HADDAM NECK	1460	
BRAIDWOOD 1	1420	
JAMES A. FITZPATRICK	1350	
BYRON 1 & 2	1240	
PALO VERDE 3	1200	
SAN ONOFRE 2 & 3	1160	
BRUNSWICK 1 & 2	1120	
EDWIN I. HATCH 1 & 2	1100	
DAVIS - BESSE 1	1090	
RIVER BEND 1	1030	
BRAIDWOOD 2	1020	
WOLF CREEK 1	999	
NORTH ANNA 1 & 2	952	
MAINE YANKEE	946	
PILGRIM 1	907	
COMANCHE PEAK 1	906	
CALLAWAY 1	902	
WNP - 2	890	
HOPE CREEK 1	830	
SUMMER 1	751	
OYSTER CREEK 1	735	
PALO VERDE 1	708	
ARKANSAS ONE 1	700	
TURKEY POINT 3	688	
LASALLE 1 & 2	687	
PALO VERDE 2	676	
CALVERT CLIFFS 1 & 2	672	
THREE MILE ISLAND 1	666	
INDIAN POINT 3	626	
ST. LUCIE 1	619	
HARRIS 1	596	
R. E. GINNA	595	
TURKEY POINT 4	592	
ST. LUCIE 2	534	
CATAWBA 1	533	
CATAWBA 2	533	
MCGUIRE 1	518	
MCGUIRE 2	518	
FORT CALHOUN 1	459	
SURRY 1 & 2	451	
SALEM 1	313	
MILLSTONE 3	211	
TROJAN	206	
ARKANSAS ONE 2	189	
DONALD C. COOK 1 & 2	188	
VOGTLE 1 & 2	188	
COOPER	187	
SOUTH TEXAS 1	172	
NINE MILE POINT 2	163	
FERMI 2	161	
SALEM 2	149	
GRAND GULF 1	136	
PALISADES	121	
MILLSTONE 1	117	
YANKEE ROWE 1	113	
ZION 1 & 2	110	
SOUTH TEXAS 2	109	
SEABROOK 1	107	
JOSEPH M. FARLEY 1	87	
PERRY 1	84	
PRAIRIE ISLAND 1 & 2	83	
BEAVER VALLEY 1 & 2	82	
QUAD - CITIES 1 & 2	80	
SUSQUEHANNA 1 & 2	72	
DIABLO CANYON 1 & 2	56	
DUANE ARNOLD	46	← NAVAL REACTORS <50
JOSEPH M. FARLEY 2	34	
LIMERICK 1 & 2	34	
DRESDEN 2 & 3	20	
CLINTON 1	11	
POINT BEACH 1 & 2	8	
H. B. ROBINSON 2	7	
KEWAUNEE	2	
RANCHO SECO 1	0.2	
BROWNS FERRY 1, 2 & 3	NA	
DRESDEN 1	NA	
FORT ST. VRAIN	NA	
HUMBOLDT BAY 3	NA	
LACROSSE	NA	
NINE MILE POINT 1	NA	
SHOREHAM 1	NA	
THREE MILE ISLAND 2	NA	

LIQUID (less tritium)

MILLSTONE 2	8.76	
SOUTH TEXAS 1	7.09	
SOUTH TEXAS 2	5.72	
SURRY 1 & 2	4.60	
SALEM 2	3.14	
OCONEE 1, 2 & 3	3.11	
SALEM 1	3.00	
DIABLO CANYON 1 & 2	2.80	
HADDAM NECK	2.69	
ZION 1	2.65	
BEAVER VALLEY 1 & 2	2.55	
MILLSTONE 3	2.47	
ARKANSAS ONE 1	2.36	
BRAIDWOOD 1	2.13	
BRAIDWOOD 2	2.13	
COOPER	2.04	
MCGUIRE 1	2.00	
MCGUIRE 2	2.00	
DONALD C. COOK 1 & 2	1.61	
HOPE CREEK 1	1.49	
CALVERT CLIFFS 1 & 2	1.42	
SEQUOYAH 1 & 2	1.22	
BYRON 1 & 2	1.18	
INDIAN POINT 1 & 2	1.06	
VOGTLE 1 & 2	1.01	
CATAWBA 1	0.978	
CATAWBA 2	0.978	
ZION 2	0.926	
ST. LUCIA 1	0.827	
FORT CALHOUN 1	0.805	
ST. LUCIE 2	0.768	
RIVER BEND 1	0.737	
HARRIS 1	0.731	
WATERFORD 3	0.730	
DRESDEN 1, 2 & 3	0.712	
NORTH ANNA 1 & 2	0.675	
GRAND GULF 1	0.645	
CRYSTAL RIVER 3	0.619	
PERRY 1	0.610	
BRUNSWICK 1 & 2	0.457	
SAN ONOFRE 1	0.403	
H. B. ROBINSON 2	0.360	
SUMMER 1	0.356	
LIMERICK 1 & 2	0.343	
WOLF CREEK 1	0.315	
INDIAN POINT 3	0.309	
BROWNS FERRY 1, 2 & 3	0.302	
EDWIN I. HATCH 1 & 2	0.301	
ARKANSAS ONE 2	0.252	
FERMI 2	0.218	
KEWAUNEE	0.206	
SAN ONOFRE 2 & 3	0.202	
MAINE YANKEE	0.187	
R. E. GINNA	0.150	
TROJAN	0.144	
DAVIS - BESSE 1	0.141	
TURKEY POINT 3	0.141	
TURKEY POINT 4	0.140	
MILLSTONE 1	0.139	
SUSQUEHANNA 1 & 2	0.134	
PRAIRIE ISLAND 1 & 2	0.130	
QUAD - CITIES 1 & 2	0.113	
JOSEPH M. FARLEY 2	0.083	
JOSEPH M. FARLEY 1	0.075	
LACROSSE	0.069	
NINE MILE POINT 2	0.063	
CALLAWAY 1	0.039	
BIG ROCK POINT 1	0.036	
JAMES A. FITZPATRICK	0.027	
CLINTON 1	0.025	
LASALLE 1 & 2	0.025	
THREE MILE ISLAND 1	0.024	
PILGRIM 1	0.016	
WNP - 2	0.015	
PEACH BOTTOM 2 & 3	0.014	
COMANCHE PEAK 1	0.012	
POINT BEACH 1 & 2	0.012	
PALISADES	0.008	
HUMBOLDT BAY 3	0.006	
YANKEE ROWE 1	0.004	
SEABROOK 1	0.002	←NAVAL REACTORS <0.002
NINE MILE POINT 1	0.00195	
RANCHO SECO 1	0.00021	
THREE MILE ISLAND 2	0.00018	
FORT ST. VRAIN	0.00008	
OYSTER CREEK 1	0.00007	
DUANE ARNOLD	NA	
MONTICELLO	NA	
PALO VERDE 1	NA	
PALO VERDE 2	NA	
PALO VERDE 3	NA	
SHOREHAM 1	NA	
VERMONT YANKEE 1	NA	

1. Naval reactors include 4 land based prototypes and over 120 ships. Total program releases are comparable to commercial reactor releases listed above.
2. Source: U. S. Nuclear Regulatory Commission report NUREG/CR - 2907, Vol. 11, October 1993

5.1.2 **Air Exhausted From Radiological Facilities**

Since nuclear work began at Subase Bangor, radiological work facility exhaust systems have been equipped with High Efficiency Particulate Air (HEPA) filters and have been monitored for radioactivity with an Environmental Monitoring System. The Environmental Monitoring System consists of a vacuum pump, filter holder, differential pressure gauges, totalizing hour meter, and connecting tubing, installed at each HEPA filter exhausted to the environment. A simplified diagram of this system is shown in Figure 5-2. The analysis procedure for the Environmental Monitoring System requires a minimum detectable activity (MDA) of less than 2×10^{-14} µCi/ml. Actual MDAs have been lower than this, and analysis results have always been "less than MDA."

Sampling probe location was determined by obtaining a velocity profile across the duct. A uniform velocity distribution indicates turbulent flow, assuring adequate mixing and entrainment of particulates to permit single point sampling. If the velocity profile did not permit single point sampling (laminar flow), an array of sampling probes could be located in accordance with ANSI N13.1-69. All NNPP systems are configured to permit single point sampling (turbulent flow).

The sampling probe inlet velocity is adjusted to provide isokinetic flow. This assures that a representative sample will be obtained.

The systems are checked weekly to verify the flow rate is within specification and the differential pressure across the filter is within prescribed limits. At a minimum, the sampling filter must be changed annually. In practice, much more frequent changes are required due to dust loading of the filter.

Figure 5-2
Simplified Diagram of Environmental Monitoring System
(Air Sampling)

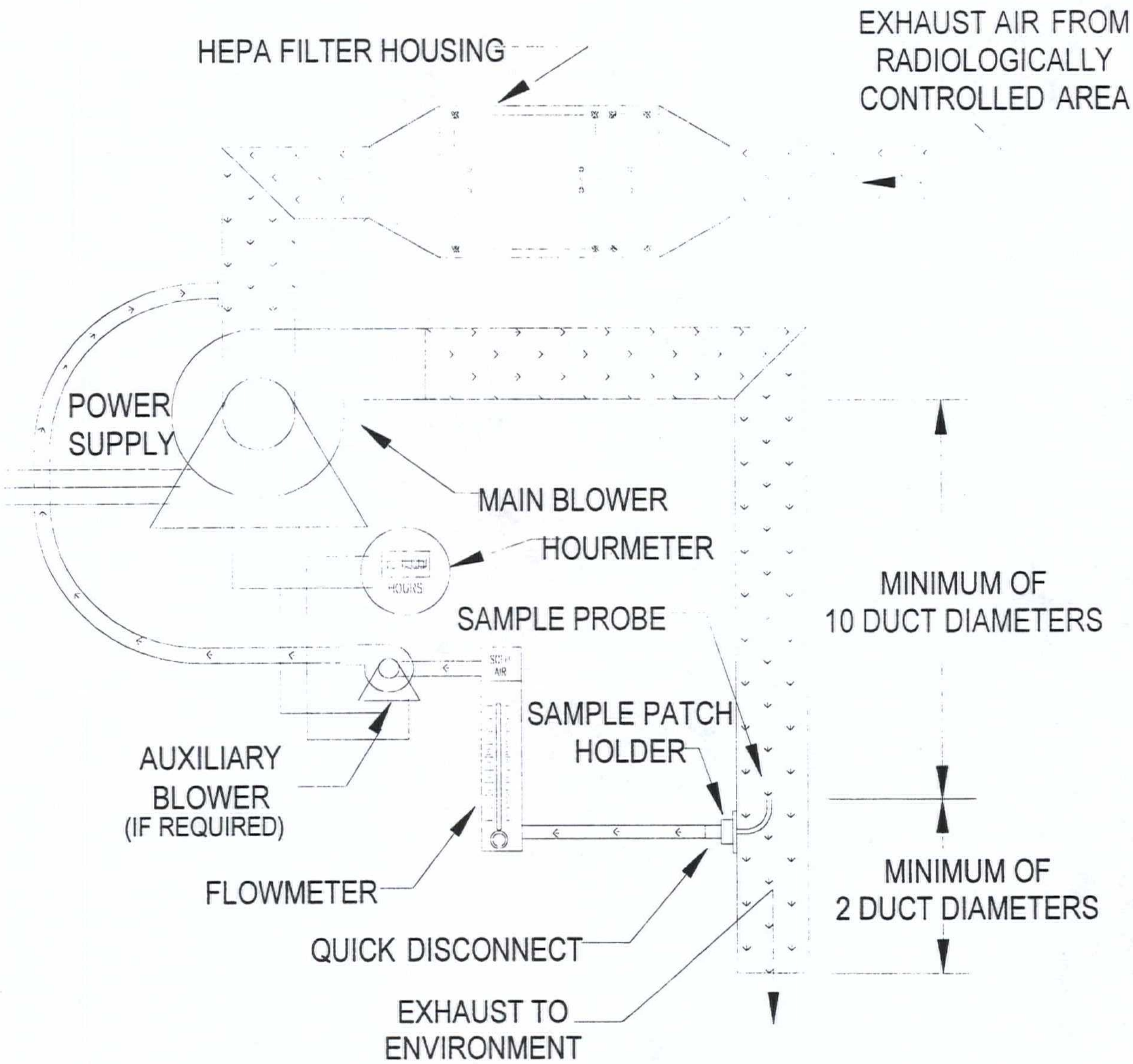


Table 5-3 summarizes the results of air exhaust monitoring. In each year the activity of air exhausted from radiological facilities has contained less total radioactivity than the naturally occurring radioactivity in an equal amount of air from the environment (this is because HEPA filters also remove natural radioactivity, such as radon daughter products).

Table 5-3
Airborne Particulate Radioactivity in Air Exhausted From Radiological Facilities vs. Background Radioactivity in Air Subase Bangor

Year	Average Facility Exhaust Air Activity Concentration μCi/ml	Total Volume Discharged From Facilities ml/yr	Total Airborne Radioactivity Discharged From Facilities μCi/yr	Average Background Air Activity Concentration μCi/ml (a)	Total Activity if Background Air Had Been Discharged μCi/yr
1996	$<1.7 \times 10^{-16}$	2.9×10^{13}	<0.005	1.4×10^{-14}	0.39
1995	$<3.1 \times 10^{-15}$	1.4×10^{14}	<0.43	1.4×10^{-14}	2.0
1994	$<3.2 \times 10^{-15}$	4.4×10^{13}	<0.14	1.2×10^{-14}	0.5
1993	$<3.5 \times 10^{-15}$	4.3×10^{13}	<0.15	1.4×10^{-14}	0.6
1992	$<3.4 \times 10^{-15}$	8.8×10^{13}	<0.30	1.3×10^{-14}	1.1
1991	$<3.2 \times 10^{-15}$	5.4×10^{13}	<0.17	1.4×10^{-14}	0.8
1990	$<3.1 \times 10^{-15}$	3.9×10^{13}	<0.12	1.2×10^{-14}	0.5
1989	$<2.7 \times 10^{-15}$	9.6×10^{13}	<0.26	1.8×10^{-14}	1.7
1988	$<3.2 \times 10^{-15}$	1.3×10^{14}	<0.42	1.4×10^{-14}	1.8
1987	$<3.2 \times 10^{-15}$	9.1×10^{13}	<0.29	1.1×10^{-14}	1.0
1986	$<3.1 \times 10^{-15}$	5.2×10^{13}	<0.16	1.9×10^{-14}	1.0
1985	$<3.1 \times 10^{-15}$	4.5×10^{13}	<0.14	1.0×10^{-14}	0.4
1984	$<3.3 \times 10^{-15}$	3.6×10^{13}	<0.12	2.4×10^{-14}	0.9
1983	$<3.3 \times 10^{-15}$	4.8×10^{13}	<0.16	1.5×10^{-14}	0.7
1982	$<3.5 \times 10^{-15}$	4.9×10^{13}	<0.17	2.0×10^{-14}	1.0
1981	$<3.1 \times 10^{-15}$	4.2×10^{13}	<0.13	1.3×10^{-14}	0.6

Notes: a. Average background values are based on measurements made at Puget Sound Naval Shipyard. Subase Bangor does not measure environmental air background levels.

These data verify that Subase Bangor air exhausts are about an order of magnitude cleaner than the air in the environment, from a radiological perspective.

EPA regulations for radionuclide emissions from non-DOE Federal facilities, including from Navy facilities, are contained in Title 40, Code of Federal Regulations, Part 61 (40 CFR 61) Subpart I.

As part of the 40 CFR 61 regulations, activities are required to report emissions unless the amounts released are less than 10 percent of the standards. To assist activities in assessing their facilities, the EPA has provided a computer code called COMPLY. Puget Sound Naval Shipyard has run this program using Subase Bangor site-specific parameters required for Level 4 analysis using COMPLY. For 1996, the most recent analysis, the COMPLY results are less than 10 percent of the standards, and Subase Bangor is exempt from the requirements for reporting in accordance with 40 CFR 61.

The NESHAP 40 CFR 61 calculations demonstrate an exposure level to the general public of less than 1.0 mrem/yr, including the contributions from trace levels of fission product gases and gaseous carbon-14 products as discussed in Sections 4.2 and 4.2.3. Noble gasses such as isotopes of argon, krypton, or xenon do not accumulate in the environment and are therefore not a potential candidate for site remediation. Also, even if radioiodines had ever been released in significant quantities (which they haven't been), they would not constitute a potential remediation issue due to their short half lives. Finally, carbon-14 does not accumulate in the environment, as discussed in Section 4.2.3.

5.1.3 **Reports of Inadvertent Releases**

Naval Nuclear Propulsion Program regulations require that formal reports be submitted to headquarters by activities when inadvertent releases of radioactivity to uncontrolled areas, to personnel, or to the environment occur. These "incident reports" have been required since the inception of the program. Subase Bangor has maintained a file of these reports dating back to 1981.

An extensive search for archive copies of incident reports was conducted. A total of nine (9) reports were related to potential radioactivity releases to the environment. A comprehensive review of all available detailed records was performed for this HRA. Table 5-4 summarizes data obtained during these reviews. These reviews verified that the affected areas were surveyed and sampled as required by regulations and that the areas were properly released from radiological controls. The release criteria for surface contamination are less than 450 pCi/100 cm^2 by swipe analysis as discussed in Section 4.4, and less than 450 pCi per 20 cm^2 scanning probe. The release criteria for soil/concrete at a spill site was formerly less than 30 pCi/g; several years ago it was reduced to less than 1 pCi/g cobalt-60 unless NNPP headquarters approves otherwise on a case basis. No such exceptions apply at Subase Bangor. Using NNPP sampling and analysis procedures, these surface and soil release criteria are at the limit of detectability above background.

The review of past incident reports also verified that any radioactive liquids lost to the environment were accounted for and included in the annual discharge reports to the Naval Nuclear Propulsion Program.

That no significant radioactivity has accumulated in harbor water, sediment, or edible aquatic species is confirmed by survey results reported elsewhere in this HRA.

Table 5-4

Summary of Reports of Potential NNPP Radioactivity Releases to the Environment

Date	Location	Volume	Activity
10-01-81 - 11-10-81	Delta Pier	NA	2 μCi
Summary: A ship inadvertently released radioactive liquid to the harbor.			
Response: NA			

Date	Location	Volume	Activity
02-22-82	Building 7201	NA	0.0009 μCi
Summary: Routine search survey found a contaminated tubing connector fitting outside of radiological areas. Follow-up surveys discovered a contaminated hydrostatic pump aboard a submarine. The pump was the likely source of the contamination on the fitting.			
Response: Both items were controlled as radioactive material. Additional search surveys found no additional radioactivity.			

Date	Location	Volume	Activity
04-15-82	Building 7201	NA	0.0028 μCi
Summary: A routine survey outside of radiologically controlled areas found three contaminated items: a wrench (0.0006 μCi), a bolt (0.00072 μCi) and an anticontamination clothing rubber glove (0.0015 μCi).			
Response: Items were immediately controlled as radioactive material. The radiological control supervisor and monitor who had previously released the material were disqualified. All radiological release of material was suspended until review and re-verification of technique. Procedures were revised to require additional overcheck survey prior to release.			

Table 5-4 (con't)
Summary of Reports of Potential NNPP Radioactivity Releases to the Environment

Date	Location	Volume	Activity
01-25-85	Delta Pier North	NA	0.09 μCi
Summary: Two workers were contaminated while working on a portable radioactive liquid waste collection tank system without anticontamination clothing or other radiological controls. The work was not authorized, but was performed due to a miscommunication. The workers walked from the pier to the Controlled Industrial Facility where the contamination was detected. Follow-up surveys detected a contaminated fitting which the workers had removed from the tank. A swipe survey of the fitting detected 0.09 μCi.			
Response: The personnel were decontaminated and the fitting was controlled as radioactive material. Additional surveys detected no additional radioactivity. The workers were disqualified from entering radiation areas. They had not been qualified to perform work which required radiological controls. Radiological control training was improved for all maintenance personnel. Training was also conducted to improve communication between those giving and receiving oral instructions.			

Date	Location	Volume	Activity
10-07-85	Delta Pier, Building 7040	NA	NA
Summary: A non-radioactive tool which was marked with yellow paint and placed in the radioactive material control system by mistake was later found outside radiologically controlled areas. Lagging paste on the tool obscured the yellow marking to both the worker and radiological control monitor when the tool was removed from a radiologically controlled area.			
Response: Surveys of the tool and all locations where it had been were all less than minimum detectable.			

Date	Location	Volume	Activity
04-12-93	Delta Pier	0.008 gallons	NA
Summary: A small amount of steam and liquid escaped from a portable radioactive liquid waste collection tank during a high temperature discharge. Steam escaped the HEPA filter. Liquid escaped from three flanges. The tank did not have an adequate water heel to quench the steam. The flange fasteners were only finger tight.			
Response: The transfer was immediately secured. Normal corrective actions for the spill (containment, clean-up, surveys, and personnel training) were taken. Surveys of the areas where liquid had been spilled were less than minimum detectable. The flanges were inspected and reassembled correctly. The HEPA filter was replaced.			

Table 5-4 (con't)

Summary of Reports of Potential NNPP Radioactivity Releases to the Environment

Date	Location	Volume	Activity
06-30-94	Delta Pier, South	NA	NA
Summary: A diver disconnecting a hull flange dropped two potentially contaminated lock washers. The washers sank to the harbor bottom.			
Response: The harbor bottom was searched unsuccessfully. Previous surveys of the washers and the other flange fasteners were all less than minimum detectable, and it was identified that these items had been controlled as "potentially contaminated" for convenience. Procedures were revised to require the use of fasteners which are not controlled as radioactive material.			

Date	Location	Volume	Activity
04-25-95	Delta Pier, South	NA	0.0011 μCi
Summary: Surveys performed after a transfer of controlled pure water to a submarine detected 0.0011 μCi on a fitting and hose.			
Response: The fitting and hose were controlled as radioactive material. Surveys of the immediate area and the rest of the system were all less than minimum detectable. Investigation determined the hose had been contaminated in November of 1994 and had been improperly released from radiological controls based solely on a swipe survey. Surveys of all areas where the hose had been since November 1994 were all less than minimum detectable.			

Date	Location	Volume	Activity
04-08-96	Delta Pier	0.8 gallons	0.0042 μCi
Summary: A ship inadvertently released radioactive liquid to the harbor.			
Response: NA			

Notes:

a. NA - data not available or not applicable to the event.

b. Spills are also assumed to have occurred within the controlled radiological work area in Building 7201. Despite the special design features of this facility, it is conceivable that some radioactivity remains (e.g., within concrete flooring). This facility will warrant special sampling and surveying in the event it is to be released from radiological controls.

5.2 **Low-Level Solid Radioactive Waste Disposal**

5.2.1 **Policy**

Solid low-level radioactive waste is generated during operation and maintenance of Naval nuclear-powered ships. This low-level waste consists primarily of contaminated rags, plastic bags, paper, filters, ion exchange resin, and scrap materials. To maintain accountability, strict controls over these materials are implemented. These controls include serialized tagging and marking, and signatures by radiologically trained personnel to document transfers of materials. Solid radioactive waste materials are packaged in strong tight containers and shielded as necessary.

From the inception of the Program, on-site disposal of solid radioactive waste has been prohibited. This policy was described in early reports such as "Radioactive Waste Disposal from U.S. Naval Nuclear Powered Ships," January 1959, Reference 13. Radioactive solid waste was shipped to disposal sites operated or authorized by the Atomic Energy Commission (AEC). In the early years of the Program, this included some AEC-authorized ocean disposal sites. Subase Bangor has not used ocean disposal. When commercially operated sites licensed by the AEC or a state under agreement with the AEC became available, the Navy's solid radioactive waste was sent to these sites. Currently, such waste is shipped to disposal sites licensed by the U.S. Nuclear Regulatory Commission or a state under agreement with the U.S. Nuclear Regulatory Commission.

The quantity of solid radioactive waste generated and shipped in any one year from Subase Bangor depends on the amount and type of support work performed that year.

All radioactive shipments in the NNPP from Subase contain only low-level radioactivity classified under Department of Transportation regulations as low specific activity or limited quantity shipments. The predominant radionuclide associated with these shipments is cobalt-60 in the form of insoluble metallic oxide corrosion products attached to surfaces of materials inside shipping containers. Most low-level shipments are made by truck. Air transport is used no more than a few times per year for the NNPP. These air shipments involve only very low levels of radioactivity and are restricted to cargo aircraft.

The policies and practices used successfully for over 40 years in managing radioactive materials and radioactive waste continue to be used currently. Reference 9 discusses and also illustrates the overall performance of the Program since 1961 in managing radioactive waste.

Facilities continue to be prohibited from disposing of radioactive waste on site. No Navy sites have active or inactive disposal areas for NNPP radioactive materials.

Submarine bases currently have agreements with Naval shipyards in their geographic area to assist in the packaging and disposal of Fleet radioactive waste. Puget Sound Naval Shipyard certifies the proper packaging and labeling of low-level radioactive waste shipments from Subase Bangor to approved disposal sites. Submarine bases have only limited storage areas for staging waste for disposal. The Program policies of minimizing waste at the point of generation and then disposing of it as soon as processing and packaging are completed continue to be applied.

5.2.2 **Records**

The annual summary of solid waste disposal is included with the annual environmental monitoring reports prepared by the Naval Nuclear Propulsion Program. A synopsis of annual solid radioactive waste data derived from available records is contained in Table 5-5. Puget Sound Naval Shipyard ships Subase Bangor radioactive waste in conjunction with shipments of shipyard radioactive waste.

All solid radioactive waste listed in Table 5-5 was disposed of at the Hanford, Washington commercial radioactive waste disposal site. Table 5-5 does not include classified components disposed of at the Hanford, Washington DOE site. No spent fuel has been shipped from Subase Bangor, since no nuclear refuelings were ever performed at the base.

The existence of the Shipyard's radioactive waste disposal records dating back to 1965 and continuing through 1996, along with the prohibition of disposing of waste on-site, provide evidence that no solid radioactive waste has been disposed of on base property.

Table 5-5
Summary of Solid Radioactive Waste Disposal From Subase Bangor

Year	Volume Cubic Feet
1996	1097.8
1995	1524
1994	601
1993	393.5
1992	238
1991	545
1990	637
1989	335
1988	262
1987	120
1986	573
1985	30
1984	82.5
1983	0
1982	0

5.3 **Mixed Waste**

Mixed waste (waste which is both hazardous and contaminated with radioactivity) has been generated during overhaul and repair of nuclear-powered ships at some NNPP facilities. However, none has been produced at Bangor, and the nature of the work performed at Subase Bangor makes it unlikely that any mixed waste would be produced at the base. It is possible that small quantities of such waste could be produced in the future.

Mixed waste generated by Subase Bangor would be handled by Puget Sound Naval Shipyard. Treatment of mixed waste would occur as specified in the Puget Sound Naval Shipyard Site Treatment Plan, in accordance with a consent order issued by the Washington State Department of Ecology in October 1995. Any such waste would be shipped elsewhere for storage or treatment.

5.4 Release of Facilities and Equipment Previously Used for Radiological Work

NNPP regulations require that activities engaged in Naval nuclear propulsion plant work compile and maintain lists of facilities, areas, and equipment that have been used in support of radiological work. These regulations further require that extensive radiological surveys be conducted when these radiological work or storage areas will no longer be used or when the area, facility, or equipment is being released from radiological control.

Such surveys include those using a gamma scintillation meter, and beta-gamma frisk surveys. Solid material samples are analyzed with a high-purity germanium detector coupled to a multi-channel analyzer. Samples are taken in defined grids. Any radioactivity detected by surveys or samples is removed and the area resurveyed or resampled until levels comparable to background are attained. Release criteria are discussed in Sections 4.4 and 5.1.3.

Results of surveys and sample analyses are formally documented and archived. For those areas being permanently released, a written report describing the area, radiological history, surveys and sampling protocol, tabulated results, and conclusions is forwarded to NNPP headquarters.

No Subase Bangor facilities, areas, and equipment used in support of radiological work have been permanently released for unrestricted use.

Pier and wharf areas adjacent to berths where nuclear ships are moored are used to locate portable radioactive liquid waste collection tanks, and occasionally serve as temporary radioactive material storage areas. Radioactive liquid waste tanks are controlled by technical working documents approved by the Radiological Engineering management of Puget Sound Naval Shipyard. Temporary radioactive material storage areas to be used for periods exceeding one week require the written approval of the shipyard's Director of Radiological Control.

When a radioactive liquid waste tank is relocated or a temporary radioactive material storage area is disestablished, beta-gamma radiological surveys are performed prior to removing signs and barriers. The area must meet the Naval Nuclear Propulsion Program limits of less than 450 pCi/100cm^2 swipe sample, or less than 450 pCi/20 cm^2 scanning probe, to be released for general use. Even then, the area is included on the list of those areas requiring permanent release as described above.

Radiological equipment, including portable work and storage enclosures, are maintained under the control of radiological control personnel until permanently released as described above. In addition, if the equipment has any crevices which could trap loose surface contamination, the item must be bulk counted before release or be disposed of as solid radioactive waste.

An example of the large-scale release of prior NNPP radiological facilities occurred when the NNPP left Ingalls Shipbuilding in Pascagoula, Mississippi. From 1958 to 1980, Ingalls Shipbuilding was engaged in the construction and overhaul of Naval nuclear-powered ships. The shipyard radiological facilities which supported this work were deactivated between 1980 and 1982. Extensive radiological decommissioning surveys were performed to verify the effectiveness of deactivation. Direct radiological surveys were performed on over 274,000 square feet of building and facility surfaces. Over 11,000 samples of these surfaces as well as soil, ground cover, and concrete were taken from all areas where radioactive work was previously performed. These samples were analyzed using sensitive laboratory equipment. In addition, both the State of Mississippi and the Environmental Protection Agency (Reference 14) performed overcheck surveys of the deactivated facilities. After these surveys were completed, the Ingalls facilities were released for unrestricted use.

As at Ingalls, extensive radiological decommissioning surveys were performed at Mare Island and Charleston Naval Shipyards to verify the removal of radioactive material. These shipyards were deactivated following the 1993 round of the Base Realignment and Closure process. At each shipyard, direct radiological surveys on over 5,000,000 square feet of building and facility surfaces and analyses of over 40,000 samples of soil, ground cover, and concrete using sensitive laboratory equipment detected no cobalt-60 other than trace concentrations in a few localized areas. Simple, proven cleanup methods were used to remediate these areas. The total amount of NNPP radioactivity removed from the environment at each shipyard was equivalent to that in a single home smoke detector (2 to 3 μCi). Both shipyards were released for unrestricted use with respect to NNPP radioactivity by the operational closure date of April 1, 1996, with state and EPA agreement.

Personnel who subsequently occupy these facilities will not receive detectable radiation exposure above natural background levels. This relatively rapid and inexpensive remediation effort was only possible due to the NNPP policy of operating its radiological facilities in a manner which does not impact the environment.

5.5 Current Radiological Facilities

Other than active radiological work and storage areas, there are no areas within Subase Bangor where radioactivity exists above natural background levels. Current NNPP radiological work and storage areas are identified in Table 5-6.

Table 5-6
Radiological Work and Storage Areas Currently in Use

Facility	Radiological Use
Building 7417	Radioactive Material Storage
Building 7429	Radioactive Material Storage
Building 7431	Radioactive Material Storage
Building 7432	Radioactive Material Storage
Building 7201, Controlled Industrial Facility	Radiological Work Facility
Building 7201, fenced area	Radioactive Material Storage
Drydock Basin	In-Transit Radioactive Material Storage
Resin Catch Tank Shed	Portable Enclosure
Portable Radioactive Waste Collection Tank (PRWCT) Shed	Portable Enclosure
Control Shed	Portable Enclosure

6.0 **Environmental Monitoring**

Since July 1973, radiological environmental monitoring has been conducted at Subase Bangor by Puget Sound Naval Shipyard (PSNS). This monitoring consists of analyzing harbor sediment, water, and marine life samples for radioactivity associated with Naval nuclear propulsion plants, radiation monitoring around the perimeter of support facilities, and related monitoring. The scope and analysis methods of PSNS monitoring are sensitive enough to identify environmental radioactivity from various sources, such as that due to airborne nuclear tests in past years. Environmental samples are also checked at least annually by a U.S. Department of Energy laboratory to ensure analytical procedures are correct and standardized within the NNPP.

The NNPP environmental monitoring program does not include monitoring within the air, soil, or ground water pathways. The procedures discussed in prior sections to control radioactivity at the source during work, as substantiated by NESHAPS calculations, document that air releases are below the level of environmental significance. The NNPP policy for spills, including immediate containment and corrective action as soon as they are identified, precludes the likelihood for soil or ground water contamination. As discussed previously, shallow ground water in near shoreline areas drains directly to the harbor without impacting drinking water wells. For these reasons, the lack of direct air, soil, or ground water monitoring within the routine environmental monitoring program is acceptable.

Sections 2.3.1 and 4.2.1 discuss the basis for cobalt-60 being the primary radionuclide of interest for the NNPP.

6.1 **Harbor Environmental Records**

Harbor environmental monitoring data consisting of sediment, water, and marine life sample analysis data are applicable to the surface water pathway.

6.1.1 **Sediment Sampling**

In 1966, PSNS implemented a uniform Program environmental monitoring protocol. PSNS has taken quarterly harbor sediment samples at Subase Bangor since July of 1973. Sediment samples have been collected quarterly through the present.

Beginning in 1966, the NNPP has published an annual report of environmental monitoring and waste disposal throughout the entire Program. These reports have been made available to federal and state regulatory agencies, state governments, and the general public. Reference 9 is the latest in this series of reports.

Each of the annual reports contains sediment sampling data. Data for sediment sampling results reported annually by Puget Sound Naval Shipyard are included in Table 6-1.

Table 6-1
Gamma Radioactivity Concentration in Harbor Sediment Samples
Subase Bangor 1973 - 1996

		No. of Samples with Co-60 Energy Range Activity, 1.1-1.4 MeV			Gross Gamma Results 0.1-2.1 MeV (a)		Specific Cobalt 60 (a)	
Year	Quarter	<3 pCi/g	3 - 30 pCi/g	>30 pCi/g	Average pCi/g	High/Low pCi/g	Average pCi/g	High/Low pCi/g
1973	3	35 (b)	0	0	0.8	1.3/0.4	NA (c)	NA
	4	15	0	0	0.8	1.5/0.4		
1974	1	15	0	0	0.8	1.1/0.5	NA	NA
	2	15	0	0	0.9	1.1/0.6		
	3	15	0	0	0.8	1.1/0.4		
	4	15	0	0	0.8	1.0/0.3		
1975	1	15	0	0	0.8	1.0/0.4	NA	NA
	2	15	0	0	0.8	1.0/0.5		
	3	15	0	0	0.8	1.1/0.4		
	4	15	0	0	0.6	0.9/0.3		
1976	1	15	0	0	0.7	1.1/<0.2	NA	NA
	2	15	0	0	0.7	1.0/0.2		
	3	15	0	0	0.7	1.0/0.4		
	4	15	0	0	0.7	0.9/<0.2		
1977	1	15	0	0	0.7	1.1/0.4	NA	NA
	2	15	0	0	0.7	1.1/0.3		
	3	15	0	0	0.7	1.0/0.3		
	4	15	0	0	0.8	1.3/0.6		
1978	1	15	0	0	0.8	1.0/0.5	<0.06	<0.09 - <0.03
	2	15	0	0	0.8	1.0/0.3	<0.07	<0.12 - <0.04
	3	15	0	0	0.7	0.9/0.4	<0.06	<0.10 - <0.02
	4	15	0	0	0.7	1.0/0.3	<0.06	<0.10 - <0.02
1979	1	15	0	0	0.8	1.1/0.4	<0.05	<0.10 - <0.02
	2	15	0	0	0.7	0.9/0.4	<0.07	<0.08 - <0.05
	3	15	0	0	0.7	1.0/0.4	<0.07	<0.09 - <0.04
	4	15	0	0	0.7	0.9/0.4	<0.06	<0.09 - <0.02
1980	1	30	0	0	0.7	1.2/0.3	<0.06	<0.09 - <0.02
	2	30	0	0	0.6	1.1/0.1	<0.06	<0.10 - <0.02
	3	29	0	0	0.6	0.9/0.1	<0.06	<0.13 - <0.02
	4	28	0	0	0.6	1.0/0.1	<0.06	<0.09 - <0.02
1981	1	30	0	0	0.7	1.3/0.2	<0.05	<0.10 - <0.02
	2	30	0	0	0.7	1.1/0.2	<0.06	<0.10 - <0.02
	3	30	0	0	0.7	1.0/0.2	<0.05	<0.09 - <0.02
	4	30	0	0	0.6	1.1/0.1	<0.05	<0.08 - <0.02
1982	1	30	0	0	0.6	1.0/0.1	<0.05	<0.09 - <0.02
	2	34	0	0	0.6	1.0/0.1	<0.06	<0.11 - <0.02
	3	34	0	0	0.6	1.1/0.1	<0.05	<0.10 - <0.02
	4	34	0	0	0.6	1.0/0.2	<0.04	<0.09 - <0.02
1983	1	34	0	0	0.8	1.4/0.1	<0.06	<0.09 - <0.02
	2	33	0	0	0.7	1.1/0.1	<0.05	<0.09 - <0.02
	3	33	0	0	0.6	1.0/0.1	<0.05	<0.11 - <0.02
	4	33	0	0	0.7	1.2/0.1	<0.05	<0.09 - <0.02
1984	1	33	0	0	0.6	1.2/0.1	<0.05	<0.09 - <0.02
	2	33	0	0	0.6	1.0/0.1	<0.05	<0.08 - <0.02
	3	33	0	0	0.6	1.1/0.2	<0.04	<0.08 - <0.02
	4	33	0	0	0.6	1.1/0.2	<0.04	<0.08 - <0.01
1985	1	33	0	0	0.8	1.2/0.2	<0.06	<0.11 - <0.03
	2	33	0	0	0.7	1.2/0.3	<0.06	<0.10 - <0.02
	3	33	0	0	0.8	1.1/0.2	<0.06	<0.14 - <0.01
	4	33	0	0	0.8	1.1/0.4	<0.06	<0.11 - <0.02

Table 6-1 (con't)

Gamma Radioactivity Concentration in Harbor Sediment Samples
Subase Bangor 1973 - 1996

		No. of Samples with Co-60 Energy Range Activity, 1.1-1.4 MeV			Gross Gamma Results 0.1-2.1 MeV		Specific Cobalt 60 (a)	
Year	Quarter	<3 pCi/g	3 - 30 pCi/g	>30 pCi/g	Average pCi/g	High/Low pCi/g	Average pCi/g	High/Low pCi/g
1986	1	33	0	0	0.8	1.9/0.1	<0.05	<0.09 - <0.02
	2	33	0	0	0.9	1.1/0.3	<0.05	<0.09 - <0.02
	3	33	0	0	0.8	1.2/0.3	<0.05	<0.09 - <0.03
	4	33	0	0	0.6	1.8/0.3	<0.06	<0.09 - <0.02
1987	1	33	0	0	1.0	2.9/0.5	<0.07	<0.11 - <0.04
	2	33	0	0	1.0	2.1/0.3	<0.07	<0.17 - <0.01
	3	31	0	0	0.9	1.1/0.8	<0.07	<0.11 - <0.04
	4	31	0	0	0.9	1.1/0.6	<0.07	<0.15 - <0.02
1988	1	31	0	0	0.7	2.2/0.1	<0.07	<0.14 - <0.03
	2	31	0	0	0.9	1.1/0.5	<0.09	<0.16 - <0.04
	3	31	0	0	0.9	2.3/0.6	<0.09	<0.19 - <0.05
	4	31	0	0	0.9	1.1/0.3	<0.06	<0.12 - <0.03
1989	1	31	0	0	0.9	2.1/0.7	<0.08	<0.14 - <0.05
	2	31	0	0	0.9	1.0/0.5	<0.07	<0.13 - <0.03
	3	31	0	0	0.8	1.1/0.6	<0.07	<0.13 - <0.03
	4	31	0	0	0.8	1.2/0.2	<0.05	<0.09 - <0.02
1990	1	31	0	0	0.8	1.1/0.2	<0.07	<0.12 - <0.03
	2	31	0	0	0.9	1.1/0.8	<0.07	<0.11 - <0.03
	3	31	0	0	0.9	1.1/0.6	<0.07	<0.12 - <0.02
	4	31	0	0	0.9	1.0/0.2	<0.07	<0.13 - <0.02
1991	1	31	0	0	0.9	1.1/0.7	<0.07	<0.13 - <0.03
	2	31	0	0	0.9	1.0/0.5	<0.07	<0.13 - <0.03
	3	31	0	0	0.9	1.1/0.7	<0.08	<0.14 - <0.03
	4	31	0	0	0.8	1.0/0.6	<0.07	<0.11 - <0.04
1992	1	31	0	0	0.9	1.0/0.8	<0.06	<0.12 - <0.03
	2	31	0	0	0.9	1.0/0.7	<0.07	<0.10 - <0.04
	3	31	0	0	0.9	1.1/0.8	<0.07	<0.13 - <0.02
	4	31	0	0	0.9	1.0/0.7	<0.06	<0.09 - <0.02
1993	1	31	0	0	1.0	1.2/0.8	<0.07	<0.12 - <0.03
	2	31	0	0	0.9	1.1/0.7	<0.07	<0.12 - <0.03
	3	31	0	0	0.9	1.1/0.8	<0.07	<0.11 - <0.04
	4	31	0	0	0.9	1.1/0.7	<0.06	<0.09 - <0.01
1994	1	31	0	0	0.9	1.1/0.8	<0.07	<0.10 - <0.02
	2	31	0	0	0.8	0.9/0.6	<0.05	<0.10 - <0.02
	3	31	0	0	0.9	1.0/0.7	<0.06	<0.11 - <0.03
	4	31	0	0	0.9	1.0/0.5	<0.06	<0.10 - <0.04
1995	1	NA	NA	NA	NA	NA	<0.035	<0.045 - <0.026
	2						<0.037	<0.054 - <0.028
	3						<0.046	<0.071 - <0.030
	4						<0.049	<0.077 - <0.030
1996	1	NA	NA	NA	NA	NA	<0.048	<0.077 - <0.027
	2						<0.034	<0.045 - <0.023
	3						<0.029	<0.046 - <0.028
	4						<0.032	<0.046 - <0.019

Notes: (a) Values preceded by a < symbol are the Minimum Detectable Activity (MDA) for that particular analysis; the sample analysis result was less than MDA. All other values are accurate to the number of significant figures shown.

(b) Thirty-five samples were taken during the initial survey performed between July 17 and August 2, 1973. The 35 samples included the 15 sample sites used in subsequent quarterly surveys and 20 one-time-only sample sites.

(c) NA - not available. Specific cobalt-60 was not determined prior to 1978. Puget Sound Naval Shipyard procedures for analysis of environmental samples were changed in 1995 when detailed radionuclide analyses began being performed for all environmental samples. "Gross gamma, cobalt-60 equivalent activity" and "cobalt-60 energy range" data are no longer determined.

Figure 6-1
Environmental Monitoring Locations
Subase Bangor
1973 - 1979

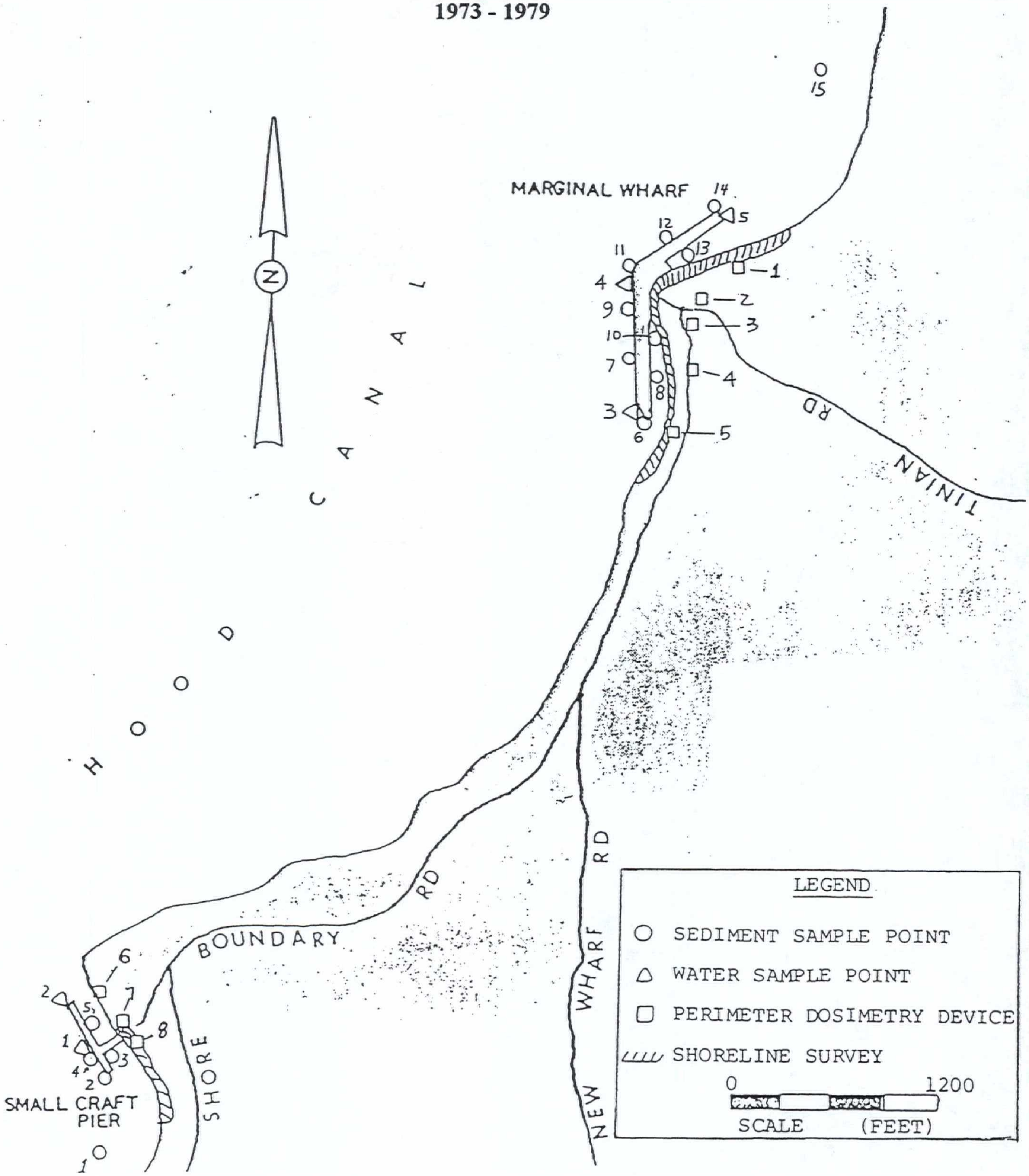


Figure 6-2
Environmental Monitoring Locations
Subase Bangor
1980 - 1991

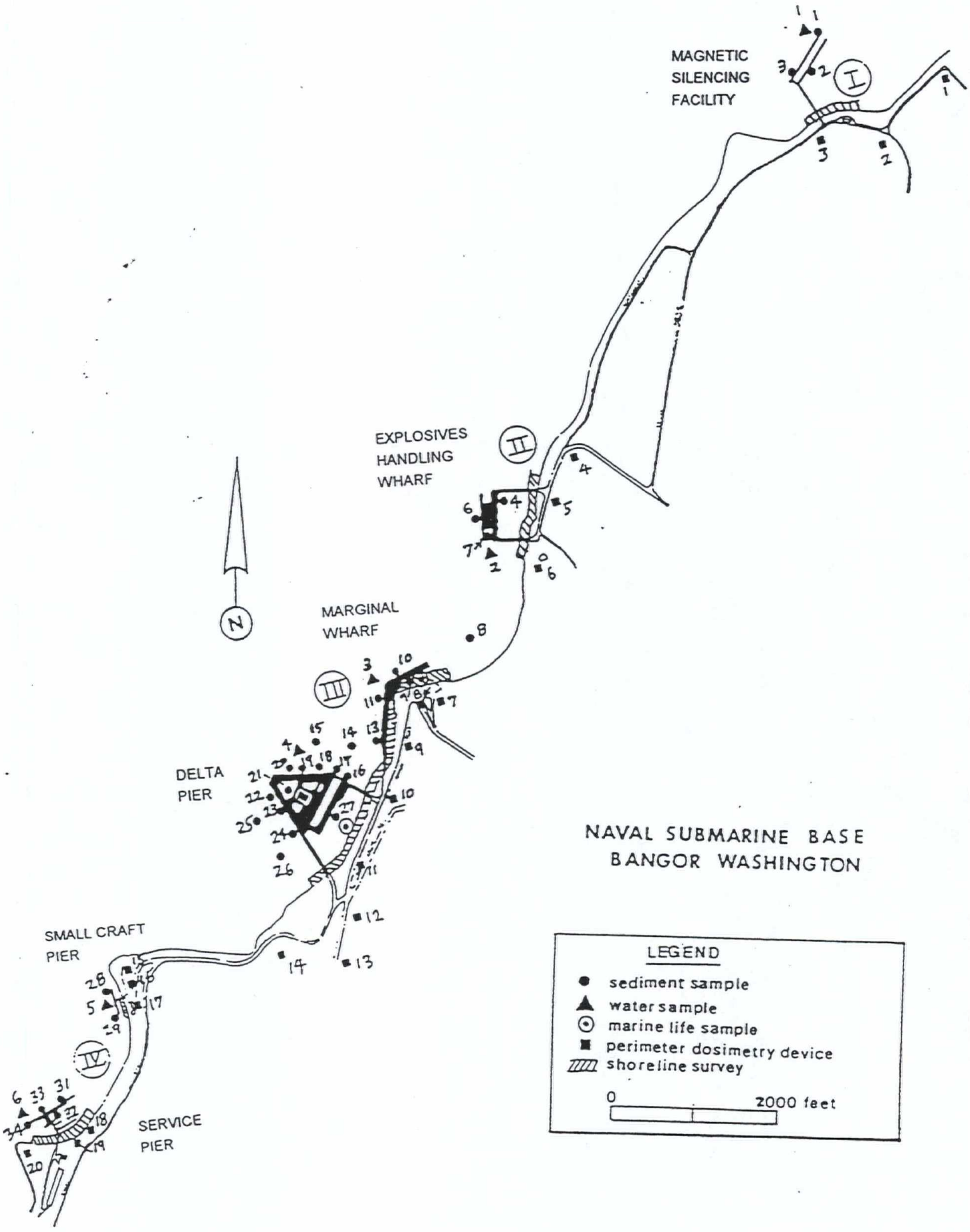
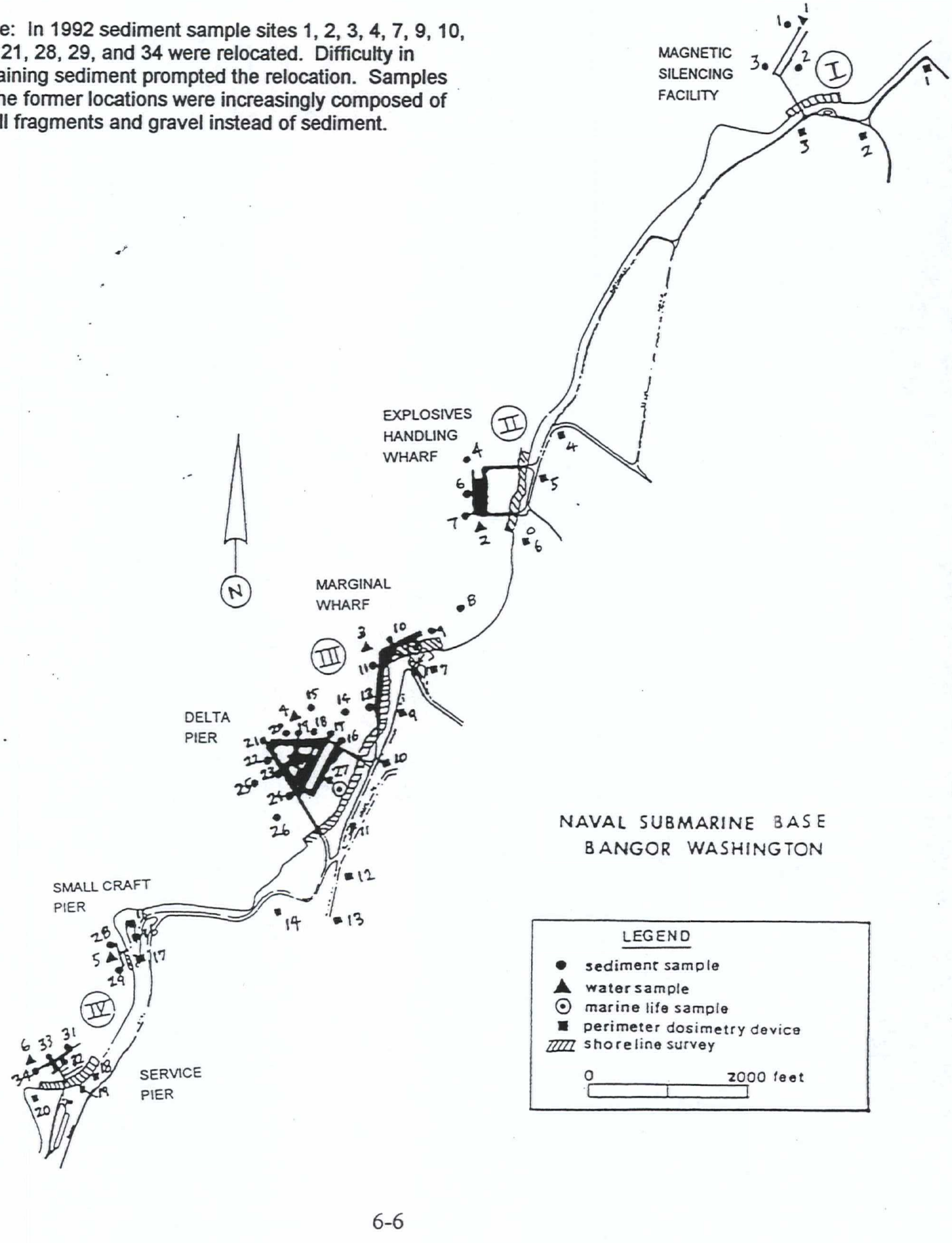


Figure 6-3
Environmental Monitoring Locations
Subase Bangor
1992 - 1996

Note: In 1992 sediment sample sites 1, 2, 3, 4, 7, 9, 10, 16, 21, 28, 29, and 34 were relocated. Difficulty in obtaining sediment prompted the relocation. Samples at the former locations were increasingly composed of shell fragments and gravel instead of sediment.



At present, 31 samples of harbor sediment are taken at Subase each quarter. Figures 6-1, 6-2, and 6-3 show the environmental monitoring locations for 1973 through 1979, 1980 through 1991, and 1992 through 1996, respectively. (The "small craft pier" on these figures, and the "Keyport/Bangor Dock" on Figure 3-4, are the same thing.) Sample locations are selected based on berthing locations of nuclear-powered ships and at points upstream and downstream of berths where tidal ebb and flood currents could deposit suspended radioactivity.

A modified 6 inch square Birge-Ekman dredge is used to obtain a sample of the top 1/2 to 1-inch of the bottom sediment. This was selected since surficial sediments are more mobile and more accessible to marine life.

Prior to 1978, sediment samples were collected in 1-quart cylindrical containers and analyzed using a sodium iodide scintillation detector in conjunction with a 100-channel "Gammascope." In 1978, a 4096-channel analyzer and germanium high resolution spectroscopy system was put into service, and actual cobalt-60 activities have been measured since then, in addition to gross gamma. (In 1995, gross gamma analyses were deleted, as noted in Table 6-1.) Collected sample material was placed in Marinelli type containers to provide more consistent counting geometry.

Sample analysis is conducted using a standardized analysis procedure which has been approved by the NNPP. All Program Fleet and shore-based activities conducting environmental monitoring utilize this method.

PSNS has utilized cross-checks by independent laboratories to verify their sample analysis results. This program continues through the present, utilizing an independent Department of Energy (DOE) laboratory. In addition, beginning in 1981, a test sample having a known quantity of cobalt-60 radioactivity has been sent to PSNS by the laboratory annually for analysis. PSNS is not provided with quantitative data beforehand. Analysis results are forwarded to the DOE laboratory for comparison with the DOE laboratory counting results and the activity known during sample preparation. PSNS results have been consistent with DOE laboratory results. Tables 6-2 and 6-3 provide side-by-side comparisons of PSNS data and DOE laboratory data for routine PSNS samples, and for the DOE laboratory test samples, respectively.

Table 6-2

Comparison of PSNS and DOE Laboratory Data for Routine Sediment Samples (pCi/g)

(KAPL=Knolls Atomic Power Laboratory)

Gross Gamma (0.1 - 2.1 MeV)							
Year	No. of Samples	Average		Range			
		PSNS	KAPL	PSNS		KAPL	
				High	Low	High	Low
1996	10	NA	NA	NA	NA	NA	NA
1995	10	NA	NA	NA	NA	NA	NA
1994	21	0.68	0.714	1.10	0.31	1.13	0.358
1993	21	0.71	0.749	1.16	0.385	1.13	0.480
1992	21	0.62	0.650	0.97	0.33	0.997	0.323
1991	21	0.68	0.704	1.00	0.45	1.06	0.462
1990	21	0.63	0.635	1.10	0.27	1.10	0.285
1989	21	0.69	0.665	1.01	0.48	1.11	0.482
1988	21	0.67	0.650	1.23	0.25	1.21	0.207
1987	22	0.77	0.722	1.46	0.45	1.05	0.271
1986	22	0.67	0.659	1.50	0.30	1.42	0.251
1985	21	0.88	0.865	1.79	0.21	1.86	0.122
1984	21	0.7	0.7	3.06	0.08	2.89	0.104
1983	22	0.6	0.5	1.43	0.09	1.13	0.096
1982	20	0.9	0.9	3.89	0.10	4.11	0.114
1981	20	0.8	0.8	2.32	0.17	2.51	0.114
1980	20	0.8	0.8	3.53	0.07	3.65	0.085
1979	16	1.1	1.0	4.66	0.13	4.52	0.189
1978	16	1.2	1.2	5.96	0.28	6.00	0.21

Cobalt-60 Energy Range (1.1 - 1.4 MeV)						
Year	Average		Range			
	PSNS	KAPL	PSNS		KAPL	
			High	Low	High	Low
1996	NA	NA	NA	NA	NA	NA
1995	NA	NA	NA	NA	NA	NA
1994	0.305	0.292	0.50	0.16	0.438	0.132
1993	0.30	0.273	0.49	0.15	0.410	0.173
1992	0.27	0.269	0.46	0.12	0.439	0.119
1991	0.30	0.281	0.46	0.14	0.490	0.185
1990	0.27	0.266	0.49	0.10	0.473	0.110
1989	0.28	0.287	0.47	0.16	0.514	0.204
1988	0.27	0.263	0.43	0.08	0.413	0.089
1987	0.30	0.283	0.75	0.13	0.459	0.120
1986	0.25	0.284	0.46	0.07	0.502	0.119
1985	0.30	0.319	0.52	0.05	0.600	0.059
1984	0.3	0.3	0.73	<0.03	0.675	<0.039
1983	NA	0.2	NA	NA	0.452	<0.037
1982	0.3	0.3	1.05	<0.04	1.23	<0.035
1981	0.3	0.3	0.61	<0.04	0.69	<0.035
1980	0.3	0.3	1.06	<0.04	1.08	0.085
1979	0.4	0.3	1.27	<0.04	1.23	0.036
1978	0.4	0.4	1.56	0.05	1.58	0.042

Specific Cobalt-60 Photopeak (b)						
Year	Average		Range			
	PSNS	KAPL	PSNS		KAPL	
			High	Low	High	Low
1996	0.052	0.0057	0.070	0.030	0.006	0.005
1995	0.036	0.0053	0.045	0.029	0.007	0.004
1994	0.063	0.059	0.100	0.019	0.092	0.022
1993	0.069	0.037	0.120	0.019	0.050	0.026
1992	0.062	0.053	0.100	0.029	0.089	0.020
1991	0.064	0.062	0.110	0.028	0.095	0.039
1990	0.054	0.073	0.097	0.013	0.112	0.035
1989	0.07	0.051	0.12	0.03	0.079	0.016
1988	0.07	0.053	0.11	0.04	0.094	0.016
1987	0.06	0.056	0.12	0.03	0.090	0.030
1986	0.05	0.042	0.10	0.02	0.080	0.012
1985	0.07	0.057	0.11	0.04	0.091	0.027
1984	0.04	0.06	0.07	0.02	0.094	0.021
1983	0.05	0.06	0.08	0.02	0.095	0.022
1982	0.06	0.06	0.13	0.02	0.113	0.020
1981	0.06	0.06	0.12	0.02	0.087	0.035
1980	0.1	0.1	0.10	0.02	0.158	0.039
1979	0.1	0.1	0.16	0.02	0.147	0.020
1978	0.1	0.1	0.13	0.02	0.134	0.026

Notes: (a) NA - not available. Only specific radionuclide analyses were performed beginning in 1995.

(b) The values for the cobalt-60 photopeak are the MDA. Actual samples were all <MDA. This table presents data from one calender quarter per year, when the KAPL comparisons were performed.

(c) These quality control comparison analyses were performed on PSNS samples, not Subase Bangor samples; hence, the difference from Subase data in Table 6-1.

Table 6-3
Comparison of PSNS and DOE Laboratory Data for Test Samples

Simulated Sediment (pCi/g)														
	Actual Conc. Co-60		PSNS Measured Co-60		Actual Conc. Cs-137		PSNS Measured Cs-137		Other Isotopes					
										Actual Conc.		PSNS Measured		
Year	Activity	+/- (a)	Activity	+/-	Activity	+/-	Activity	+/-	Isotope	Activity	+/-	Activity	+/-	
1996	1.10	0.03	1.07	0.05	1.10	0.05	0.95	0.06						
1995	1.12	0.06	1.13	0.17	1.18	0.06	1.04	0.21						
1994	1.21	0.06	1.2	0.22	1.29	0.06	1.2	0.20						
1993	2.00	0.06	1.8	0.29	2.00	0.08	1.8	0.28						
1992	1.05	0.03	1.0	0.20	1.15	0.05	1.0	0.21						
1991	1.1	0.03	1.0	0.21	1.1	0.05	1.1	0.20						
1990	1.12	0.03	1.0	0.21	1.06	0.04	1.1	0.20						
1989	1.09	0.03	1.16	0.23	1.36	0.05	1.28	0.22						
1988	1.05	0.03	0.99	0.22	1.11	0.05	1.02	0.19	Co-57	0.49	0.01	0.50	0.08	
1987	0.9	0.03	0.85	0.19	0.85	0.03	0.78	0.19						
1986	1.14	0.03	1.13	0.21	0.87	0.03	0.82	0.15	Cr-51	9.38	0.24	8.72	0.67	
1985	2.16	0.06	2.22	0.35	0.6	0.02	0.46	0.16	Co-57	0.47	0.01	0.50	0.07	
1984	1.97	0.05	1.86	0.30	0.92	0.03	0.97	0.18	Co-57	0.59	0.02	0.61	0.11	
1983	0.7	0.02	0.84	0.19	1.56	0.06	1.58	0.23	Cs-134	1.44	0.04	1.64	0.25	
1982	1.28	0.03	1.21	0.29	0.8	0.03	0.84	0.19	Cr-51	3.46	0.09	4.12	2.29	
1981	0.79	0.03	0.80	0.20	1.16	0.03	1.48	0.23	Mn-54	0.99	0.05	0.92	0.21	
1980	1.05	0.26	0.90	0.22	1.10	0.21	1.16	0.22	Co-57	1.96	0.15	2.10	0.18	

Simulated Air Patch (pCi)				
	Actual Activity Co-60		Shipyard Measured Co-60	
Year	Activity	+/-	Activity	+/-
1996	203	6	209	7
1995	209	7	195	32
1994	207	7	190	6.1
1993	391	11	350	10
1992	191	6	160	43
1991	202	6	250	41
1990	199	5	190	36
1989	191	5	210	18
1988	218	5.7	201	6.5
1987	145	4	141	5
1986	168	4	159	28
1985	259	7	274	7
1984	288	8	289	8
1983	210	5	212	5
1982	142	4	139	5
1981	261	7	277	7
1980	184	5	223	7

Note: (a) Error term (+/-) is given as 2 sigma counting error.

During 1987 the U.S. Environmental Protection Agency (EPA) conducted independent assessments of radioactivity in the environs of Puget Sound Naval Shipyard and Subase Bangor. Measurements at Subase included radioactivity in four harbor water samples, nineteen bottom sediment samples, one sediment core sample, and nine marine life samples. Radioactivity measurements and assessments of the results are reported in Reference 15. EPA results are consistent with PSNS environmental monitoring program results. The Environmental Protection Agency survey concluded:

> "A trace amount of Co-60 (0.04±0.01 pCi/g) was detected in one sediment sample at PSNS. All other radioactivity detected in the eighty sediment samples is attributed to naturally occurring radionuclides or fallout from past nuclear weapons tests and the Chernobyl reactor accident in 1986.
>
> "Results of core sampling did not indicate any previous deposit of Co-60 in the sediment.
>
> "Water samples contained no detectable levels of radioactivity other than those occurring naturally.
>
> "External gamma-ray measurements did not detect any increased radiation exposure to the public above natural background levels.
>
> "Based on these surveys, current practices regarding nuclear-powered warship operations have resulted in no increases in radioactivity that would result in significant population exposure or contamination of the environment."

Prior to July 1973, the State of Washington Department of Social and Health Services (DSHS) was the only agency to routinely monitor Subase Bangor for radioactivity. Reference 16 summarizes annual DSHS sample results for Subase Bangor and other Naval facilities on Puget Sound from 1970 through June of 1975. None of the State's samples reported in Reference 16 detected cobalt-60 or other radionuclides associated with the NNPP.

The data collected by the shipyard, the Environmental Protection Agency, and the State of Washington over the period 1970 through 1996 clearly support the conclusion that any trace (though undetected) levels of residual cobalt-60 that may be present in harbor sediment: a) contribute a negligable increase to background radioactivity levels; and b) pose no hazard to the public, either directly or via the food chain, and pose no hazard to the ecological systems of the region.

6.1.2 **Harbor Water Monitoring**

The Naval Ordnance Systems Command Environmental Health Center performed an environmental radiation study of the Dabob Bay area in 1969. The study included 25 water samples collected near Subase Bangor's Small Craft Pier (K/B Dock). Water samples were analyzed for gross beta radioactivity. Reference 17 reports the results of the study. The conclusion of the study of the Dabob Bay area, including Subase Bangor, states:

> "Analysis of this data does not reveal the presence of radioactive materials other than those which are normally present."

Beginning in July 1973 and continuing through the present, quarterly samples of water from Hood Canal have been collected and analyzed. Sampling locations are shown on Figures 6-1, 6-2, and 6-3.

Sample locations are selected based on areas where radioactive liquids could have been discharged and at upstream and downstream locations.

Between 1973 and 1977, six-liter samples were counted in shipyard-made Marinelli containers with a 3-inch by 3-inch sodium iodide scintillation detector and a multichannel analyzer. Since 1978, a 4096-channel multichannel analyzer and germanium high resolution spectroscopy system has been used to count 500 ml samples, and actual cobalt-60 activity is determined. Like sediment samples, a Marinelli container is used for water sample analysis.

Since 1978, the counting procedure for water samples has been the same as for sediment samples. The quality control sample sent annually by the DOE laboratory serves to verify both sediment and water sample analysis results.

Two drinking water samples and two surface water samples were taken at Subase Bangor by the U.S. Environmental Protection Agency (EPA) in 1987. The two surface water samples were collected near Delta Pier. Reference 15 reports that no cobalt-60 or other radionuclides associated with nuclear-powered warships were detected. No cobalt-60 has been detected in any water sample taken by PSNS since the inception of the monitoring program in 1973. A review of both shipyard gamma counting results and the series of environmental monitoring reports published annually by the Naval Nuclear Propulsion Program reveals that no cobalt-60 has ever been detected in harbor water samples. Quarterly data for each year is reported annually by the shipyard. Subase Bangor water sample date is presented in Tables 6-4 and 6-5.

The conclusions reached by the Navy in its annual reports are confirmed by Reference 15. The Reference 15 conclusion is quoted in Section 6.1.1.

Table 6-4

Water Samples, 1978 - 1996, Collected by PSNS at Subase Bangor

Year	Number of Samples	Range Cobalt-60 Photopeak µCi/ml
1996	24	$<1.2 - <3.8 \times 10^{-8}$
1995	24	$<1.6 - <4.0 \times 10^{-8}$
1994	24	$<1.7 - <6.4 \times 10^{-8}$
1993	24	$<2.8 - <8.1 \times 10^{-8}$
1992	24	$<1.3 - <7.6 \times 10^{-8}$
1991	24	$<1.6 - <8.1 \times 10^{-8}$
1990	24	$<3.0 - <8.2 \times 10^{-8}$
1989	24	$<1.5 - <8.7 \times 10^{-8}$
1988	24	$<2.1 - <9.0 \times 10^{-8}$
1987	24	$<3.2 - <9.5 \times 10^{-8}$
1986	24	$<1.5 - <8.0 \times 10^{-8}$
1985	24	$<3.0 - <13 \times 10^{-8}$
1984	24	$<2.9 - <8.4 \times 10^{-8}$
1983	24	$<2.9 - <9.4 \times 10^{-8}$
1982	23	$<3.0 - <7.2 \times 10^{-8}$
1981	20	$<3.2 - <7.2 \times 10^{-8}$
1980	20	$<3.2 - <7.2 \times 10^{-8}$
1979	20	$<3.3 - <7.4 \times 10^{-8}$
1978	20	$<3.3 - <12 \times 10^{-8}$

Table 6-5

Water Samples, 1973 - 1977, Collected by PSNS at Subase Bangor

Year	Number of Samples	Gross gamma, 0.1 - 2.1 MeV µCi/ml
1977	20	$<2.2 \times 10^{-8}$
1976	20	$<2.2 \times 10^{-8}$
1975	20	$<2.3 \times 10^{-8}$
1974	20	$<2.2 \times 10^{-8}$
1973 (a)	10	$<2.4 \times 10^{-8}$

Note: (a) Ten water samples were collected in 1973 - five in the third quarter and five in the fourth quarter.

6.1.3 **Marine Life Sampling**

The Naval Ordnance Systems Command Environmental Health Center performed an environmental radiation study of the Dabob Bay area in 1969. A total of fourteen marine life samples were collected along the shore of Hood Canal and analyzed for gross beta radioactivity. Reference 17 reports the results of the study. The conclusion of the study of the Dabob Bay area, including Subase Bangor, states:

> "Analysis of this data does not reveal the presence of radioactive materials other than those which are normally present."

On July 31, 1973, PSNS collected oysters from a section of the beach approximately 1200 feet south of Marginal Wharf. The oysters were shucked and the meat was combined into a sample that weighted 964 grams. Sample analysis indicated less than 0.15 pCi/g gross gamma radioactivity.

Beginning in 1977, Program activities conducting environmental monitoring were required to obtain marine life samples during July of each year. Samples include available species of marine plants, mollusks, and crustaceans from sample locations shown in Figure 6-1. Analysis data of marine life samples taken since 1978 are shown in Table 6-6 (the species of mollusk collected varies from year to year). The following species of marine life were collected and analyzed:

Scientific Name	Common Name
Marine Plant:	
Ulva	Green Sea Lettuce
Mollusk:	
Protothaca staminea	Littleneck Clam
Venerupis staminea	
Callithaca tenerrima	Thin-Shell Littleneck
Mytilus edulis	Edible Mussel
Tresus nuttalla	Horse Clam
Clinocardium nuttalla	Basket Cockle
Saxidomus gigateus	Butter Clam
Crustacean:	
Cancer productus	Red Rock Crab
Cancer magister	Dungeness Crab

Marine life samples were collected by the EPA in 1987 at six Subase Bangor sites. Radioactivity measurements and assessment of the results are reported in Reference 15. No cobalt-60 was detected in any marine life sample taken during these surveys. Radioactive silver-110m was detected in two mollusk samples. The source of the silver-110m was not determined. The EPA concluded it may have been fallout from the Chernobyl reactor accident.

On the basis of the data shown in Table 6-9, the Naval Ordnance Systems Command Environmental Health Center survey reported in Reference 17, and the findings of the EPA survey reported in Reference 15, there has been no accumulation of cobalt-60 in marine organisms as a result of operation of nuclear-powered ships or work on those ships at Subase Bangor.

Table 6-6
Marine Life Monitoring Results
Subase Bangor

Year	Sample Type	Average Gross Gamma pCi/g	Average Cobalt-60 Energy Range Gamma pCi/g	Maximum Specific Cobalt-60 (a) pCi/g
1996	Crustacean	NA (b)	NA	<0.02
	Mollusk	NA	NA	<0.04
	Marine Plant	NA	NA	<0.02
1995	Crustacean	NA	NA	<0.07
	Mollusk	NA	NA	<0.02
	Marine Plant	NA	NA	<0.05
1994	Crustacean	0.12	0.07	<0.06
	Mollusk	0.14	0.10	<0.05
	Marine Plant	0.23	0.19	<0.05
1993	Crustacean	0.15	0.11	<0.09
	Mollusk	0.17	0.11	<0.07
	Marine Plant	0.23	0.25	<0.19
1992	Crustacean	0.11	0.05	<0.05
	Mollusk	0.12	0.08	<0.06
	Marine Plant	0.41	0.27	<0.12
1991	Crustacean	0.08	0.05	<0.07
	Mollusk	0.17	0.15	<0.16
	Marine Plant	0.30	0.17	<0.12
1990	Crustacean	0.09	0.10	<0.05
	Mollusk	0.75	0.19	<0.12
	Marine Plant	0.12	0.06	<0.05
1989	Crustacean	0.09	0.09	<0.06
	Mollusk	0.12	0.13	<0.05
	Marine Plant	0.17	0.12	<0.06
1988	Crustacean	0.08	0.05	<0.06
	Mollusk	0.11	0.08	<0.06
	Marine Plant	0.15	0.11	<0.09
1987	Crustacean	<0.08	<0.09	<0.08
	Mollusk	0.16	0.12	<0.02
	Marine Plant	0.24	0.18	<0.06
1986	Crustacean	0.14	0.14	<0.06
	Mollusk	0.16	0.11	<0.02
	Marine Plant	0.29	0.33	<0.09
1985	Crustacean	0.07	<0.06	<0.05
	Mollusk	0.11	0.10	<0.11
	Plant	0.28	0.29	<0.05
1984	Crustacean	0.11	0.11	<0.03
	Mollusk	0.09	0.11	<0.05
	Marine Plant	0.25	0.15	<0.03
1983	Crustacean	0.10	0.10	<0.04
	Mollusk	0.14	0.07	<0.03
	Marine Plant	0.29	0.22	<0.10
1982	Crustacean	0.10	0.11	<0.03
	Mollusk	0.07	0.07	<0.02
	Marine Plant	0.18	0.20	<0.03
1981	Crustacean	0.11	0.14	<0.05
	Mollusk	0.17	0.15	<0.13
	Marine Plant	0.36	0.27	<0.08
1980	Crustacean	0.06	0.08	<0.06
	Mollusk	0.08	0.12	<0.05
	Marine Plant	0.24	0.18	<0.03
1979	Crustacean	0.09	0.09	<0.08
	Mollusk	0.15	0.15	<0.05
	Marine Plant	0.34	0.34	<0.05
1978	Crustacean	0.08	0.18	<0.02
	Mollusk	0.19	0.19	<0.10
	Marine Plant	0.35	0.38	<0.11

Notes: (a) Samples analyzed with a high resolution germanium detector and 4096-channel analyzer. Values preceded by "<" are the minimum detectable activity.

(b) NA - not available. Only specific radionuclide analyses were performed beginning in 1995.

6.1.4 **Core Sampling**

No Hood Canal sediment core samples have been collected by PSNS.

The EPA collected one core sample in 1987. The sampling site was just south of Delta Pier. Reference 15 reported that all radionuclides identified in the sample were attributed to naturally occurring radionuclides or fallout. The radionuclide content of the core sample showed no significant differences with depth or in comparison to the surface sediment samples taken at the same site.

6.2 **Dredging Records**

Dredging is occasionally conducted at Subase Bangor to maintain the prescribed depth at piers and wharves. Since 1975, annual environmental monitoring reports prepared by PSNS have normally stated whether or not dredging has occurred, its location, and its volume. Additional sources of dredging information are Reference 2 (Final Remedial Investigation Report) and correspondence with Subase Bangor's Public Works Department. The following dredging has occurred at Subase Bangor:

- Dredging occurred in 1977 and 1978 during construction of Delta Pier. (Specifics not available.)

- In 1986 approximately 10,500 cubic meters were removed from an area south and east of the Small Craft Pier (K/B Dock). Spoils were disposed at Four Mile Rock in Elliot Bay.

- In 1987 approximately 2,700 cubic meters were removed from the caisson moorage area north and east of the drydock. Spoils were disposed upland on Subase Bangor in the area west of Archerfish Road and south of Runner Road.

- In 1994 approximately 3,560 cubic meters were removed from the caisson moorage area north and east of the drydock. The spoils were disposed in Puget Sound at the Port Gardener site south of Whidbey Island.

Neither PSNS nor Subase Bangor have sampled dredge spoils or dredge spoil disposal sites for radioactivity since sediment sampling data have not shown any radionuclides associated with the NNPP.

The amount of naturally occurring radioactivity removed from the region in the thousands of cubic meters of spoil, primarily potassium-40 in organic detritus, would far exceed the total upper limit cobalt-60 radioactivity in Subase sediment even if all the sediment removed from the Subase contained cobalt-60 at the limit of detectability for the samples taken. This is based on information from Reference 12 on sea sediment potassium-40 content (5.7-32 pCi/g) and a cobalt-60 detectability limit on the order of 0.1 pCi/g.

6.3 **Perimeter Radiation Records**

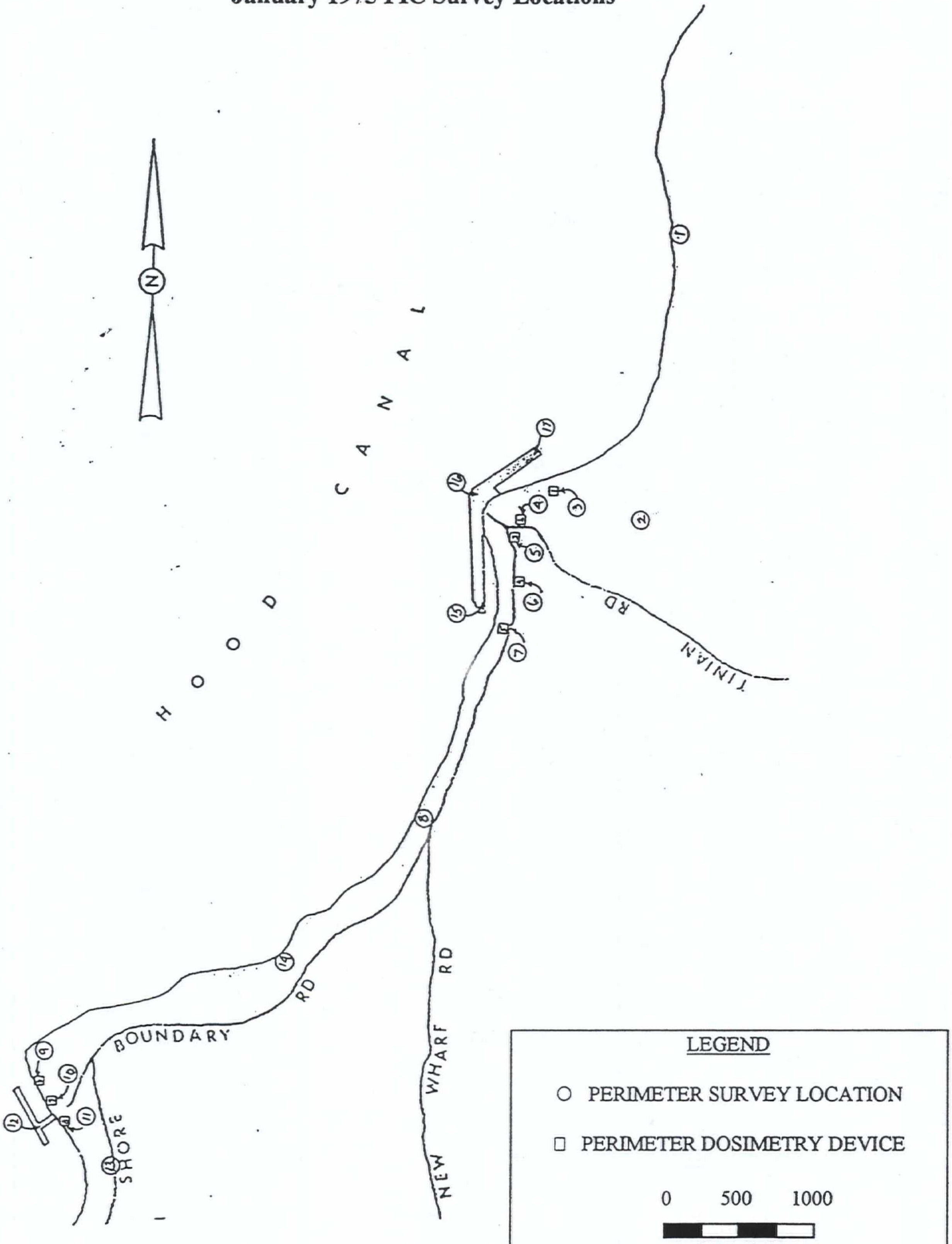
Beginning in the third and fourth quarters of 1973, beta-gamma film badges were posted outside of controlled radiation areas to ensure that unmonitored personnel within the Subase and the general public were not exposed to radiation levels above natural background. They were changed monthly. Film badges were replaced with thermoluminescent dosimeters (TLDs) in 1974. TLDs are replaced quarterly. Figures 6-1, 6-2, and 6-3 show the locations of posted perimeter dosimetry devices.

In January 1975 PSNS performed a special survey of seventeen locations at Subase Bangor with a Reuter-Stokes pressurized ion chamber (PIC). Shoreline readings ranged from 4.9 to 6.5 μR/hr with an average of 5.9 μR/hr. Readings taken on piers ranged from 6.2 to 6.4 μR/hr with an average of 6.2 μR/hr. Control readings taken over land ranged from 4.9 to 6.2 μR/hr with an average of 5.7 μR/hr. Figure 6-4 shows the survey locations. In December 1978 PSNS performed a special survey of the eight environmental TLD locations at Subase Bangor with a Reuter-Stokes PIC. The readings ranged from 4.6 to 7.0 μR/hr with an average of 5.8 μR/hr.

During August 1980 PSNS performed another special survey of Subase Bangor with a Reuter-Stokes pressurized ion chamber (PIC). Readings were taken at the 49 locations shown in Figure 6-5. The PIC readings ranged from 4.7 to 7.4 μR/hr with an average of 6.4 μR/hr. The PIC survey locations included the 17 environmental TLD locations.

The special PIC surveys performed by PSNS provide additional evidence that the radiation levels at Subase Bangor's environmental monitoring locations are natural background radiation levels.

Figure 6-4
January 1975 PIC Survey Locations



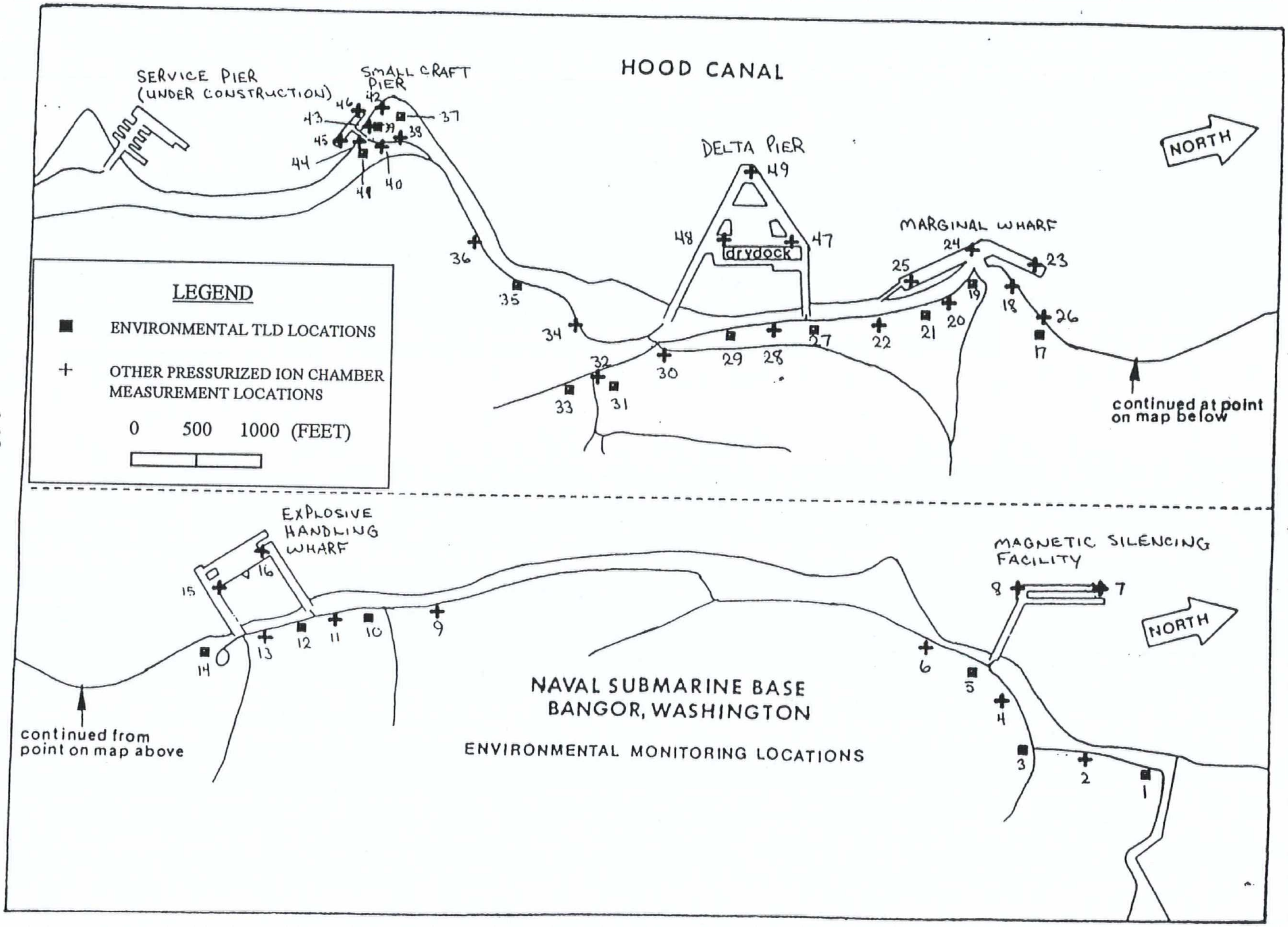


Figure 6-5
August 1980 PIC Survey

Beginning in 1978, clusters of five TLDs were posted at background locations, replacing the single TLD posted previously. Examples of background locations include: Naval Undersea Warfare Engineering Station (Keyport), Marine Corps Rifle Range (Camp Wesley Harris), and Naval Fuel Depot (Manchester). This method provided a better statistical basis for background determination and improved reliability.

Results of perimeter radiation monitoring are reported quarterly to the Naval Nuclear Propulsion Program. Table 6-7 lists annual summary results of the perimeter monitoring program since 1974, when the use of TLDs was initiated. The results of the monitoring verify that radiation exposure to the general public is indistinguishable from natural background.

Table A-1 of Reference 18 lists the annual total body dose due to natural sources in the vicinity of Subase Bangor as approximately 87 mrem (9.9 μR/hr): 46 mrem is due to terrestrial sources of natural radioactivity and 41 mrem is due to cosmic radiation. Reference 18 is cited extensively by the National Council on Radiation Protection and Measurements (NCRP) as a continuing source of data for natural background radiation exposure estimates. This referenced estimate for natural background radiation exposure rate in the vicinity of Subase Bangor is consistent with data in Table 6-8, which is a tabulation of values reported in Reference 15, PSNS data, and Subase Bangor TLD fourth quarter data for 1994.

Table 6-7
Perimeter Radiation Monitoring
Subase Bangor
1974-1996

Year	Quarter	Exposure Rate Range mrem/qtr		Average Exposure Rate mrem/qtr	
		Background	Perimeter	Background	Perimeter
1974	1	13.7 - 16.9	13.1 - 14.7	15.3	13.8
	2	14.1 - 15.2	12.2 - 14.9	14.7	14.3
	3	15.3 - 16.9	14.1 - 16.9	16.2	15.4
	4	15.1 - 17.3	14.1 - 16.8	15.9	15.0
1975	1	15.3 - 16.6	14.1 - 15.3	15.8	14.7
	2	15.4 - 16.7	14.1 - 16.5	16.2	15.3
	3	15.4 - 17.1	14.1 - 16.3	16.2	15.3
	4	15.1 - 16.6	13.6 - 15.7	15.8	14.7
1976	1	14.9 - 16.7	13.7 - 16.0	15.8	14.9
	2	15.0 - 16.5	13.9 - 15.9	15.8	14.9
	3	15.2 - 16.8	13.4 - 16.0	16.2	15.0
	4	15.5 - 17.1	14.0 - 16.9	16.1	15.2
1977	1	14.6 - 16.2	13.5 - 15.8	15.4	14.6
	2	14.6 - 16.6	12.5 - 16.3	15.6	14.8
	3	15.3 - 17.6	14.0 - 16.2	16.6	15.4
	4	15.1 - 16.7	14.0 - 16.2	15.7	14.9
1978	1	15.5 - 17	13.9 - 16.8	16.4	15.2
	2	15.7 - 17	14.3 - 15.9	16.4	15.0
	3	15.5 - 17	14.7 - 16.7	16.4	15.4
	4	15.2 - 18	13.9 - 17.2	16.2	15.2
1979	1	15.0 - 17	14.1 - 16.5	16.0	15.3
	2	14.3 - 17	13.6 - 15.8	15.6	14.8
	3	15.0 - 18	14.2 - 16.7	16.3	15.4
	4	14.6 - 17	13.9 - 16.8	16.1	15.2
1980	1	15.3 - 16.6	14.4 - 17.3	15.9	15.6
	2	14.8 - 17.1	14.1 - 17.7	16.1	15.8
	3	14.9 - 17.4	14.4 - 17.2	16.2	16.2
	4	15.1 - 17.1	14.3 - 17.5	16.0	15.8
1981	1	15.7 - 17.6	14.6 - 18.0	16.7	16.3
	2	15.6 - 16.9	14.8 - 17.1	16.1	15.9
	3	15.8 - 17.6	14.6 - 18.0	16.7	16.3
	4	15.4 - 17.6	15.0 - 18.2	16.5	16.4
1982	1	15.6 - 17.4	14.9 - 16.9	16.4	16.1
	2	15.4 - 16.8	14.5 - 17.4	16.0	15.7
	3	16.0 - 17.5	14.6 - 17.6	16.7	16.3
	4	15.5 - 17.0	15.0 - 17.6	16.3	16.2
1983	1	15.3 - 17.5	14.7 - 18.1	16.3	16.1
	2	14.7 - 17.0	14.4 - 17.5	16.4	15.9
	3	15.1 - 17.0	14.4 - 17.3	16.2	15.9
	4	15.3 - 17.1	14.5 - 18.1	16.2	15.8

Table 6-7 (con't)
Perimeter Radiation Monitoring
Subbase Bangor
1974-1996

Year	Quarter	Exposure Rate Range mrem/qtr		Average Exposure Rate mrem/qtr	
		Background	Perimeter	Background	Perimeter
1984	1	14.8 - 17.0	13.5 - 16.7	15.5	15.3
	2	15.8 - 17.4	14.4 - 17.3	16.6	16.2
	3	16.2 - 17.7	14.7 - 18.7	17.0	16.5
	4	16.1 - 18.4	16.1 - 19.0	17.1	17.2
1985	1	16.2 - 17.5	15.8 - 18.8	16.9	16.8
	2	15.8 - 17.3	14.8 - 17.6	16.6	16.3
	3	15.0 - 16.1	14.4 - 16.7	15.7	15.5
	4 (a)	17.3 - 18.6	16.1 - 19.4	18.0	18.0
1986	1	15.1 - 16.5	13.9 - 16.8	15.7	15.4
	2	15.9 - 17.6	15.0 - 18.9	16.8	16.5
	3	16.3 - 17.7	15.1 - 18.1	16.9	16.5
	4	16.2 - 18.2	15.4 - 17.5	17.1	16.5
1987	1	15.2 - 17.0	15.0 - 17.0	16.1	16.0
	2	15.6 - 17.2	15.4 - 18.0	16.5	16.7
	3	13.0 - 16.8	15.1 - 17.6	16.4	16.3
	4	16.1 - 17.8	15.2 - 18.3	17.2	17.0
1988	1	16.6 - 18.4	16.3 - 18.6	17.2	17.3
	2	13.1 - 17.9	15.6 - 19.2	16.2	17.1
	3	13.4 - 15.6	13.1 - 16.6	14.4	14.1
	4	13.7 - 15.6	11.5 - 16.2	14.6	14.5
1989	1	14.1 - 15.9	13.7 - 16.1	15.0	14.9
	2	14.2 - 16.8	13.2 - 16.7	15.4	15.0
	3	14.2 - 16.8	11.6 - 16.9	15.5	15.1
	4	14.5 - 16.2	13.7 - 17.4	15.5	15.4
1990	1	12.9 - 16.0	12.8 - 17.3	15.1	14.6
	2	14.4 - 16.4	13.8 - 17.4	15.5	15.3
	3	14.5 - 16.4	14.2 - 17.6	15.4	15.5
	4	15.0 - 16.5	14.0 - 17.5	15.8	15.7
1991	1	15.0 - 16.0	12.5 - 19.3	15.9	15.3
	2	12.9 - 16.3	12.9 - 17.8	14.8	15.0
	3	14.6 - 17.4	13.7 - 19.2	15.9	15.6
	4	15.6 - 18.1	14.1 - 18.1	16.5	16.0
1992	1	13.8 - 16.3	13.2 - 16.9	15.1	14.9
	2	12.9 - 17.8	11.9 - 16.7	14.8	14.2
	3	14.0 - 16.6	12.4 - 16.8	15.2	15.0
	4	13.9 - 16.3	13.3 - 18.4	15.1	15.0
1993	1	12.9 - 16.2	12.4 - 16.7	14.4	14.6
	2	13.5 - 16.7	12.5 - 15.7	14.7	14.7
	3	14.2 - 17.0	12.8 - 17.3	15.4	15.4
	4	14.0 - 16.6	13.8 - 17.6	15.1	15.1

Table 6-7 (con't)
Perimeter Radiation Monitoring
Subase Bangor
1974-1996

Year	Quarter	Exposure Rate Range mrem/qtr		Average Exposure Rate mrem/qtr	
		Background	Perimeter	Background	Perimeter
1994	1	13.4 - 15.8	12.8 - 17.3	14.9	14.9
	2	13.2 - 17.8	11.7 - 18.8	14.9	14.8
	3	11.7 - 16.6	12.0 - 18.0	15.0	14.8
	4	12.0 - 15.4	12.6 - 16.1	14.3	14.5
1995	1	14.5 - 16.2	13.4 - 17.4	15.4	15.2
	2	14.6 - 16.4	13.1 - 18.2	15.5	16.0
	3	14.7 - 16.6	13.3 - 16.9	15.5	14.9
	4	14.8 - 16.3	13.6 - 18.5	15.5	15.7
1996	1	14.7 - 16.1	13.2 - 17.9	15.4	15.5
	2	15.7 - 16.4	14.3 - 17.2	16.1	15.6
	3	16.0 - 18.1	14.7 - 17.4	16.9	16.6
	4	16.1 - 18.1	15.1 - 18.4	16.9	16.6

Note: (a) Fourth quarter 1985 values are for 14 weeks, instead of the normal 13 weeks.

Table 6-8
Perimeter Radiation Monitoring Comparison
Subase Bangor

Year	Survey	Ref.	Exposure Rate Range µR/hr	Average Exposure Rate µR/hr
1975	PSNS (PIC)	NA		
	Shoreline		4.9 - 6.5	5.9
	Piers		6.2 - 6.4	6.2
	Background Land		4.9 - 6.2	5.7
1978	PSNS (PIC)	NA		
	Shoreline		4.6 - 7.0	5.8
1980	PSNS (PIC)	NA		
	Shoreline		5.0 - 7.4	6.5
	Piers		4.7 - 6.8	6.0
1987	EPA (PIC & portable scintillation)	16		
	Shoreline south of Delta Pier		8.0 - 9.0	8.5
	Shoreline north of Explosives Handling Wharf		7.0 - 10.0	8.5
1994 4th Quarter	Subase (TLDs)	NA		
	Shoreline		5.8 - 7.4	6.6

Note: NA - not applicable

EPA concluded in Reference 15 that "External gamma-ray measurements did not detect any increased radiation exposure to the public above natural background levels." This conclusion applied to Subase Bangor as well as PSNS and is consistent with the Navy findings reported annually for the past 25 years in Reference 13 and successive reports through Reference 9.

The State of Washington Department of Health has measured ambient radiation levels near Subase Bangor with TLDs. State results are consistent with the results of PSNS's environmental monitoring program and are reported in the State's annual environmental monitoring reports. For example, the State reported in Reference 19 that in 1991 Subase Bangor's quarterly ambient gamma radiation level ranged from 0.12 to 0.17 mrem/day (equals 5.0 to 7.1 μR/hr, or 11.0 to 15.5 mrem/quarter). For the same period, Table 6-7 reports average quarterly perimeter TLD readings between 15.0 and 16.0 mrem/quarter.

6.4 **Shoreline Monitoring Records**

Puget Sound Naval Shipyard has conducted gamma radiation surveys of selected shore areas uncovered at low tide at Subase Bangor since the fourth quarter of 1973. The purpose of this monitoring is to determine if any radioactivity has washed ashore. These surveys are conducted during the second and fourth quarters of the year. Areas are selected based on the likelihood of suspended radioactivity being deposited by tidal currents upstream and downstream of nuclear ship berthing areas. Two or more background readings are taken at least thirty feet from the high water line at each survey location.

Table 6-9 summarizes the results of these surveys. The surveys were performed with a PRM-5N/SPA-3 gamma scintillation survey meter with a 2-inch by 2-inch sodium iodide detector. This instrument is calibrated to permit distinguishing between natural and non-naturally occurring radioactivity; it is not calibrated for the direct conversion of count rate data to natural background radiation dose rates.

Table 6-9
Shoreline Radiation Monitoring
Subase Bangor

Year	Average Background Count Rate kcpm	Shoreline Count Rate Range kcpm
1996	2.5	1.5 - 4.3
1995	2.7	1.4 - 4.8
1994	2.8	1.7 - 4.5
1993	3.0	1.9 - 4.5
1992	3.0	2.2 - 4.0
1991	2.8	1.8 - 4.0
1990	2.7	1.8 - 3.8
1989	2.7	1.9 - 6.0
1988	2.7	1.9 - 5.4
1987	3.1	2.4 - 5.5
1986	2.7	1.3 - 5.0
1985	2.7	1.5 - 4.0
1984	2.6	2.0 - 4.8
1983	2.5	1.7 - 5.0
1982	2.6	1.8 - 5.3
1981	2.6	1.8 - 5.3
1980	2.9	2.2 - 5.6
1979	3.8	2.5 - 6.5
1978	3.4	2.0 - 6.0
1977	3.0	2.3 - 5.5
1976	3.7	3.0 - 6.7
1975	3.0	2.7 - 6.0
1974	3.9	2.8 - 4.5
4th Quarter 1973	3.2	2.0 - 6.0

From fourth quarter 1973 through fourth quarter 1979, the shorelines near the Marginal Wharf and the Small Craft Pier (K/B Dock) were surveyed (Figure 6-1). Starting the first quarter of 1980, the shoreline survey was enlarged to include areas near the Magnetic Silencing Facility and the Explosive Handling Wharf. Also, the shoreline survey area along Marginal Wharf was extended to include the Delta Pier; see Figures 6-2 and 6-3. These areas are located within Subase and are thus readily accessible for monitoring.

The data of Table 6-9 show that since 1973 there has been no measurable increase in radioactivity along monitored shorelines.

6.5 **Drydock Sampling Records**

Drydocks routinely used by nuclear-powered ships are surveyed annually due to the potential to release radioactivity into the drainage and pumping systems. The results of drydock drain sampling are listed in Table 6-10.

Annual radiation surveys are also performed in drydocks when they are empty using a portable gamma survey instrument. The gamma radiation measurements are taken in a predetermined grid pattern covering the entire drydock floor. These surveys consistently find radiation levels indistinguishable from those in similar areas where no NNPP work has been performed.

The results show that NNPP activities have had no measurable effect on normal background radiation levels.

Table 6-10
Drydock Drain Sediment Samples

Year	Number of Samples	Average Gross Gamma (0.1 - 2.1 MeV) pCi/g	Average Co-60 Energy Range Gamma (1.1 - 1.4 Mev) pCi/g
1996	NA	NA	NA
1995	NA	NA	NA
1994	3	1.9 (1.3 Avg. MDA) (b)	<MDA (1.0 Avg. MDA)
1993	2	3.9 (2.3 Avg. MDA)	<MDA (2.1 Avg. MDA)
1992	NA	NA	NA
1991	NA	NA	NA
1990	7	3.8 (1.8 Avg. MDA)	1.4 (1.2 Avg. MDA)

Notes: a. NA - not available.
b. MDA - Minimum Detectable Activity.

6.6 **Routine Radiological Surveys**

To ensure proper posting of radiation areas, gamma surveys are performed weekly in occupied radiological areas, including on piers and in the drydock alongside nuclear ships. Monthly surveys are performed on any potentially contaminated ducts, piping, or hoses in use. Surveys are performed quarterly in locked, unoccupied areas.

To verify no environmental release of contamination, surveys for loose surface contamination are conducted either each shift, daily, or weekly, depending on the work site and potential for release.

Search surveys are conducted to identify uncontrolled radioactive material outside of radiologically controlled areas. Surveys using a beta-gamma frisker and a gamma scintillation type survey meter are performed in areas and buildings where no radioactive work is performed or radioactive material is stored. These searches are conducted on a revolving basis such that all Repair Department maintenance and storage areas are surveyed every year. These surveys rarely find uncontrolled NNPP radioactivity. Of all the findings of the search surveys, only one involved potential release to the environment and listing on Table 5-4 (2/22/82 listing).

SECTION 7.0

7.0 **Residual Radioactivity**

Of all the environmental radioactivity data collected, analyzed, and reported by the Naval Ordnance Systems Command Environmental Health Center in 1969, by the State of Washington since 1970, by Puget Sound Naval Shipyard since July 1973, and by the U.S. Environmental Protection Agency in 1989, no cobalt-60 or other radioactivity attributable to NNPP work at Subase Bangor has ever been detected.

SECTION 8.0

8.0 **Assessment of Environmental Impact**

Reference 20, "Guidance for Performing Preliminary Assessments under CERCLA," lists four pathways of possible environmental transport, each evaluated by three elements. These pathways include ground water, surface water, soil exposure, and air. The elements are the likelihood of release (including the likelihood of a substance migrating through a specific pathway), the waste characteristics, and the targets.

The following sections evaluate the data and information presented in this report within the framework of Reference 20.

Reference 21 calculates the annual dose to individuals from pathways derived from the requirements of 10 CFR 50 (Reference 22), for Puget Sound Naval Shipyard (a typical NNPP Naval shipyard; due to far greater workload, Puget would have a higher potential radioactive source term than exists at Subase Bangor, and provides a conservative comparison). Elements of the 10 CFR 50 pathways are comparable to the air, soil exposure, and surface water pathways evaluated by the protocol of Reference 20. It is informative to compare the results of these assessments in order to quantify the potential exposures via the pathways considered in Reference 20.

8.1 **Ground Water Pathway**

The ground water pathway considers potential exposure threats to drinking water supplies via migration to and within aquifers. It may also impact surface water and areas where ground water discharges.

That no radioactivity to infiltrate the aquifers exists above background levels is established in evaluating the soil exposure pathway in Section 8.3.

As discussed in Section 3.3.3.3, there are four aquifers underlying Subase Bangor: the Perched Aquifer, Semi-Perched Aquifer, Sea Level Aquifer, and Deep Aquifer. Contaminants, if present, could enter the Perched Aquifer through direct recharge from precipitation, and possibly the lower aquifers via leakage through overlying layers; however, there is no indication of aquifer interconnections. The gradient of the upper aquifer is very flat (less than 6 inches in one-half mile). At Floral Point, and by inference for the whole near shoreline area, the Perched Aquifer flows parallel to topography outward into Hood Canal. No drinking water is obtained from Hood Canal.

8.1.1 **Release Mechanisms Affecting Ground Water**

Radioactivity being released to ground water is the least likely mechanism. This could conceivably occur as a result of a release to the soil, atmosphere, or surface water. The radioactivity, which is primarily in an insoluble particulate form, would have to infiltrate through the soil to the ground water. As discussed above and in Section 3, no drinking water wells would be affected.

8.1.2 Ground Water Targets

Primary targets are defined as populations served by drinking water wells that are suspected to have been exposed to a hazardous substance. There has been no suspected NNPP radioactivity release from the site to ground water; thus, no primary targets are identified.

Secondary targets include populations served by all drinking water wells within four miles of the site that are not suspected to have been exposed to a hazardous substance. Approximately 12,000 people reside within four miles of Delta Pier. All on-base residents and most off-base residents within four miles of Delta Pier obtain their drinking water from wells.

There are no Wellhead Protection Areas within the region. Since ground water within the four mile zone has uses other than drinking water, it would be considered a resource.

8.1.3 Ground Water Pathway Assessment

There has been no identifiable release of radioactivity which could threaten the ground water in the vicinity of Subase Bangor and no mechanism by which a potential contaminant could be transported to ground water users. Since ground water flow is into the harbor, harbor monitoring would detect any accumulation of environmental radioactivity from the ground water pathway; such monitoring has found no evidence of environmental radioactivity release via ground water.

8.2 Surface Water Pathway

The surface water pathway considers potential exposure threats to drinking water supplies, to human food chain organisms, and to sensitive environments.

Hood Canal is a salt water estuary; it is not used for drinking water. The other bodies of surface water associated with Subase Bangor (Hunter's Marsh, Wilkes Marsh, Devil's Hole, and Cattail Lake) are small lakes and marshes which do not supply drinking water.

Analytical data collected by the shipyard consisting of harbor water, biota, and sediment samples, along with data reported in 1987 by the Environmental Protection Agency, have not detected cobalt-60 in any water, marine biota, or sediment since sampling was begun.

There are no primary sensitive environments within the 15-mile tidal influence zones of concern. Secondary sensitive environments consist of wetlands along the shorelines. Wetlands frontage exceeds 20 miles.

8.2.1 **Release Mechanisms Affecting Surface Waters**

Air release mechanisms can disperse radioactivity to local surface waters, but the potential effect of low level discharges via the air pathway is very small. Of greater potential concern would be direct liquid and solid material discharges to surface water. Leaks or ruptures from tanks stored or being moved pierside could spill their contents into the harbor; the NNPP has a periodic maintenance program for radioactive liquid tanks which includes visual inspections inside the tanks and hydrostatic tests to help prevent potential leaks. Additionally, spillage of radioactive liquids to the Subase storm drain system could ultimately reach the harbor. Leakage to ground water could also pass to surface water, should it ever occur.

8.2.2 **Surface Water Targets**

Surface water targets are subdivided into drinking water, human food chain, and environmental.

Figure 3-12, Surface Waters With Domestic Water Rights, lists 62 named surface waters with domestic water rights within the 15 mile target distance. In most cases the listed surface waters are used by only a few (one to three) households. At an average of two households per named surface water and four people per household, about 500 people reside in houses with surface water domestic water rights.

Sport and commercial fishing occur within the 15 mile target distance limit. Economically important fish and shellfish resources are discussed in Section 3.3.3.4. The most commercially important migratory fish species in Hood Canal is chum salmon, followed by chinook, coho, and pink salmon. Commercially important resident ground fish species include English sole, rock sole, Pacific cod, surf perch, and dogfish. Intertidal and subtidal shellfish populations in Hood Canal also support significant commercial and recreational fisheries. Predominant species are oysters, geoducks, Dungeness crab, shrimp, horse clams, butter clams, and Manila littleneck clams.

The estimated annual production of 10,000 to 100,000 pounds per year for the shellfish fisheries in the Kitsap basin is based on harvest/production values prior to 1982, when some waters were closed. At the time of peak production, all species of salmon produced in Kitsap basin ranged from 200,200 to 462,100 pounds per year for the years 1966 to 1971. The smelt and herring annual harvests are estimated to be greater than 1,000 to 10,000 pounds per year.

Table 8-1 lists all surface water bodies within the 15 mile tidal influence zone.

Table 8-1
Water Bodies Within The 15 Mile Tidal Influence Zone

	East Shore Hood Canal	
Port Gamble Bay	Big Beef Creek	Stavis Bay
Big Valley Creek	Little Beef Creek	Stavis Creek
Anderson Creek	Seabeck Bay	Frenchman's Cove
Big Beef Harbor	Seabeck Creek	Boyce Creek
	West Shore of Hood Canal	
Bywater Bay	Dosewallips River	McDaniel Cove
Squamish Harbor	Pleasant Harbor	McDonald Creek
Thorndike Bay	Duckabush River	Fulton Creek
Fisherman Harbor		
	Dabob Bay	
Tarboo Bay	Indian George Creek	Marple Creek
Tarboo Creek	Quilcene River	Jackson Creek
Quilcene Bay	Jackson Cove	Turner Creek
Donovan Creek	Spencer Creek	

There are no critical habitats as defined in 50 CFR 424.02 within the tidal influence zone.

A variety of ecosystems exist at Subase Bangor, including mixed coniferous forests, recovering logged areas and grasslands, freshwater wetlands, freshwater lakes and ponds, and marine intertidal and subtidal zones. The diversity of ecosystems provides important habitats for a variety of species, some uncommon in western Washington. Although there are no known federal endangered or threatened floral or faunal species inhabiting Subase Bangor at this time, the bald eagle has been sighted in the area.

Sensitive environments are defined as terrestrial or aquatic resources, fragile natural settings, or other areas with unique or highly-valued environmental or cultural features. Typically, areas that fall within the definition of "sensitive environment" are established and/or protected by State or Federal law. Examples include National Parks, National Monuments, habitats of threatened or endangered species, wildlife refuges, and wetlands. As discussed in Section 3.3.3.4, Subase Bangor contains three wetlands: Devil's Hole, Cattail Lake, and Hunter's Marsh.

No national parks or monuments, national seashore or lake shore recreational areas, national preserves, federal wilderness areas, federal Scenic or Wild Rivers, wildlife management areas, or state designated natural areas have been identified within the tidal influence zone.

State parks within 15 miles upstream or downstream of Subase Bangor include Kitsap Memorial State Park, Scenic Beach State Park, Pleasant Harbor State Park, and Dosewallips State Park.

Wetlands within the 15-mile radius of Subase Bangor exceed 20 miles, the maximum assigned value under PA or HRS scoring.

8.2.3 **Surface Water Pathway Assessment**

Previous sections of this report have established that no drinking water intakes from either surface or ground water could be affected by any potential release via discharge, precipitation run-off, or percolation. Surface drainage (precipitation run-off and run-off of accidental discharges, if any) in the industrial area is always toward Hood Canal. The nearest drinking water intake from surface waters is Dog Fish Creek, about two and one-half miles east of Delta Pier. The creek drains into Liberty Bay. If percolation did occur at the base it would be to Hood Canal.

Table VI of Reference 21 lists estimated annual exposures to the maximally exposed individual from ingestion of aquatic organisms and from recreational use of Sinclair Inlet from cobalt-60 and tritium. Uniform distribution of radioactivity in water, sediment, and on the shoreline is also assumed. Table 8-2 is based on Reference 21.

Table 8-2

Estimated Annual Dose to an Individual from Maximum Annual Liquid Effluent Release

Pathway	Cobalt-60		Tritium	
	Critical Organ	Estimated Dose millirem	Critical Organ	Estimated Dose millirem
Ingestion of aquatic organisms	Lower large intestine	2.0×10^{-5}	Whole body	3.1×10^{-5}
Shoreline	Whole body	2.3×10^{-4}		
Swimming	Whole body	2.6×10^{-5}		
Boating	Whole body	1.5×10^{-5}		

These calculated values are based on the maximum assumed annual release of 0.001 curie for cobalt-60 and 0.100 curie for tritium. These values conservatively bound the levels of radioactivity in several thousand gallons of unprocessed reactor coolant; such a release has never occurred at Subase Bangor, and has not occurred in the NNPP in over 20 years. Hence, these are very conservative estimates.

According to Table 9-7 of Reference 6, the annual dose to an individual due to radionuclides in the body (primarily potassium-40) is about 40 mrem. When this value is compared to the dose due to ingestion of seafood in Table 8-2, were the seafood contaminated with the maximum conceivable level of NNPP radioactivity, it is seen that radiation exposure due to the consumption of seafood is about 0.0001 percent of the dose due to natural radionuclides in the body.

The Navy concludes that radioactivity in surface waters will not damage sensitive environments as described by Reference 20. As discussed above and in Section 6, no water, marine biota, or sediment samples have detected cobalt-60, nor have any shorelines within the littoral zone accumulated any radioactivity associated with the NNPP. This evidence supports the conclusion that there has been no environmentally detrimental release of radioactivity to surface waters surrounding Subase Bangor.

8.3 **Soil Exposure Pathway**

The soil exposure pathway considers potential exposure threats to people on or near the site who may come into contact with a hazardous substance via dermal exposure, soil ingestion, or plant uptake into the human food chain.

Subase Bangor is actively engaged in NNPP work. As such, there are radiological facilities containing radioactivity associated with this work. These facilities and the radiological controls applied to prevent contamination of workers and the environment are discussed in other sections of this report.

For areas and facilities other than those discussed above, this report concludes that there is no likelihood for exposure to humans or to the environment. This conclusion is based on the following:

- Perimeter radiation levels have consistently been comparable to background radiation levels as measured by Puget Sound Naval Shipyard (PSNS) and the Environmental Protection Agency (EPA).

- Shoreline surveys conducted by PSNS and the EPA found no radionuclides along the shore attributable to Naval Nuclear Propulsion Program activities.

- Results of drydock surveys and samples have not shown measureable cobalt-60 radioactivity.

- There have been no reported releases of NNPP radioactivity onto soil at Subase Bangor.
- There have been no reported airborne releases of NNPP radioactivity at Subase Bangor which could have transported radioactivity onto soil.
- There has been no solid NNPP radioactive waste disposal on or near Subase property, as documented by regulatory prohibition, review of historical disposal records, and review of measured radiation levels.

Since the above evidence would result in a "no likelihood of exposure" finding, the other elements of the soil exposure pathway do not need to be evaluated.

8.3.1 **Release Mechanisms Affecting Soil**

The release mechanisms discussed in the air pathway section could deposit radioactivity in the soil of affected areas. Radioactive liquid spills to the soil would be much more localized and concentrated than soil contamination resulting from low level airborne radioactivity releases. Liquid spills with the highest potential for reaching the soil are related to activities performed outside of radiological work areas. These activities include connections of tanks to ships, tank to tank transfers, movement of tanks within the industrial area, and the movement of smaller liquid containers such as plastic bottles. None of these activities are performed near any unprotected soil; they are performed in the drydock, on the piers, or on the paved areas of the industrial area.

Spills of radioactive liquids inside work facilities would generally be contained within that facility but could reach the soil through cracks in building materials or by leaching through porous building materials such as concrete. Also, in the event of a fire in a work facility, the large volumes of water needed to control the fire could result in the transport of radioactive materials into the soil.

8.3.2 **Soil Exposure Targets**

There are no residences, schools, or daycare facilities within 200 feet of any potential source of NNPP radioactivity.

There are about 8,000 employees working on the base, including Subase and all tenant commands.

There are no terrestrial sensitive environments that have been identified within a four-mile radius of Subase Bangor.

There is no land resource use for commercial agriculture or commercial livestock production or grazing within a four-mile radius of Subase Bangor. The base sells its marketable timber.

8.3.3 Soil Exposure Pathway Assessment

The ground deposition element in the airborne pathway of Reference 21 is directly related to the soil exposure pathway. For this calculation only cobalt-60 is considered since, of the radionuclides listed in Table V of Reference 21, it is the only particulate. Although most noble gases have particulate daughters, the transport of the gaseous parent disperses and dilutes the eventual dry deposition and rainout of particulate daughters to such an extent that their dose contribution is negligible.

Table A-1 of Reference 18 lists the annual total body dose due to natural sources in the vicinity of Subase as approximately 87 mrem (9.9 μR/hr): 46 mrem (5.2 μR/hr) is due to terrestrial sources of natural radioactivity and 41 mrem (4.7 μR/hr) is due to cosmic radiation. Reference 18 is cited extensively in Reference 6 as a continuing source of data for natural background radiation exposure estimates. This value is consistent with data presented in Reference 21, with Bangor's perimeter surveys, and with surveys done by the EPA.

The maximum individual annual total body dose due to soil exposure from 0.001 curie of cobalt-60 ground deposition would be about 0.08 mrem, as listed in Table V of Reference 21. Table 5-3 shows that the calculated maximum airborne release of NNPP radioactivity occurred in 1988 and totaled $<4.2 \times 10^{-7}$ curie. Presuming all this activity is deposited on the soil of interest, this is still a factor of about 2,000 less than the 0.001 curie used for Reference 21 calculations. Hence, the actual maximum individual total body dose through the soil pathway would be approximately 0.00004 mrem/yr. This is about 0.0001 percent of the natural terrestrial background, or alternatively, this yearly dose is less than one one-hundredth of the hourly exposure from natural sources of radioactivity from the earth.

Puget Sound Naval Shipyard concludes there has been no adverse impact on human health or the environment due to the soil exposure pathway.

8.4 **Air Pathway**

The air pathway considers potential exposure threats to people and to sensitive environments via migration through the air.

As discussed in Section 5, air discharged from radiological work facilities contains less radioactivity than an equivalent amount of environmental air containing naturally occurring radioactivity. When quality analytical evidence shows that exhaust air from a facility is cleaner than environmental air and the facility has a long history of air control measures, such as HEPA filtered and monitored exhausts, no individual on-site or within the four mile radius of concern is receiving significant exposure above that being received from naturally occurring radionuclides.

Other potential sources of airborne radioactivity, such as from contaminated soil or spills of contaminated liquids, have been discussed in other sections of this report. Based on the lack of detectable soil contamination, and the immediate containment and recovery actions taken for spills, Puget Sound Naval Shipyard considers these potential sources of airborne radioactivity have been eliminated from consideration.

8.4.1 **Release Mechanisms Affecting the Air**

The methods employed to prevent the release of radioactivity into the atmosphere were discussed in Section 4.4 and have proven to be extremely effective. Nevertheless, consideration of atmospheric releases is necessary since such releases would potentially allow radioactivity to contact the soil and surface water. Some mechanisms that could cause an atmospheric release of radioactivity follow.

8.4.1.1 **Potential Releases from Ventilation Systems**

Facilities that are used for radioactive work or work with radioactive materials are potential sources of airborne radioactivity. High efficiency particulate air (HEPA) filtered ventilation systems are used in these facilities and could fail before or during work and allow radioactive particulates to enter the atmosphere. Potential failure modes for HEPA filters include: improper installation, damage during installation or use, improper differential pressure testing, or exceeding HEPA filter capacity. In addition, duct work associated with these ventilation systems could fail or become damaged causing an uncontrolled release.

8.4.1.2 **Potential Releases from Storage Areas**

The primary atmospheric release potential from radioactive material storage areas would be a fire. NNPP regulations specify that buildings where radioactive materials are stored shall be constructed and equipped with fire protection systems in accordance with Reference 23. These provisions include building construction, fire detection and alarm systems, automatic sprinkler systems, portable fire extinguishers, and fire hydrants. In addition to structure requirements, NNPP regulations: require that materials be stored in fire retardant containers; prohibit welding, burning, or other operations that could cause a fire without prior authorization; and require periodic inspections and fire drills.

Another potential release mechanism is the possibility of the loss of containment for items being stored, including tears in packaging material.

8.4.1.3 **Potential Releases from Collection Tanks**

Tanks containing radioactive liquid effluent present a potential for atmospheric release. If a tank were to rupture or leak, evaporation of the liquid could allow radioactive particles to become airborne. Rupture or leakage could result from corrosion of the tank, excessive pressure build-up, or human error in valve positioning. A release could also occur if a tank were to overflow during a liquid transfer.

8.4.2 **Air Targets**

Target populations under the air pathway consist of people who reside, work, or go to school within the 4-mile target distance limit around the site. Preliminary Assessment air pathway targets also include sensitive environments and resources.

Targets are evaluated on the basis of their distance from the site. Those persons closest to the site are most likely to be affected and are evaluated as primary targets. The nearest individual would be an on-site worker.

Like the other migration pathways, a release must be suspected in order to score primary targets for the air pathway. Releases to the air pathway, however, are fundamentally different from releases to the other migration pathways. Depending on the wind, air releases may disperse in any direction. Therefore, when a release is suspected, all populations and sensitive environments out to and including the 1/4 mile distance category are evaluated and scored as primary targets. Because air releases are quickly diluted in the atmosphere, targets beyond the 1/4 mile distance are evaluated as secondary targets.

As with other migration pathways when a release is not suspected, the residential, student, and worker population within the entire 4-mile target distance limit is evaluated as the secondary target population. The population distribution for the secondary target population is given in Sections 3 and 8.3.2.

Sensitive environments are defined as terrestrial or aquatic resources, fragile natural settings, or other areas with unique or highly-valued environmental or cultural features.

Typically, areas that fall within the definition of "sensitive environment" are established and/or protected by State or Federal law. Examples include National Parks, National Monuments, habitats of threatened or endangered species, wildlife refuges, and wetlands. Sensitive environments are discussed in Section 8.2.2.

As discussed in Section 3.3.3.4, Subase Bangor contains three major wetlands: Devil's Hole, Cattail Lake, and Hunter's Marsh. Except for wetlands, there are no sensitive environments within 1/2 mile of Subase Bangor.

The resources factor accounts for land uses around the site that may be impacted by release to the air:

- Commercial agriculture
- Commercial silviculture (e.g. tree farming, timber production, logging)
- Major or designated recreation area (e.g., municipal swimming pool, campground, park)

There are no commercial agriculture land resources within 1/2 mile of Delta Pier. Subase Bangor has a managed logging program and recreation areas.

8.4.3 **Air Pathway Assessment**

Of the pathways considered in Reference 21, the plume immersion and inhalation pathways best fit the model of Reference 20.

Tables V and VII of Reference 21 present the results of calculated radiation dose estimates for immersion and inhalation. For comparative purposes, the total body dose to the maximally exposed individual is used in all cases.

Reference 21 calculates an annual total body dose of 0.0044 mrem for immersion and 0.00026 mrem for inhalation, for radionuclides of NNPP interest. This gives a combined dose of 0.0047 mrem for this pathway. For inhalation, only cobalt-60 and carbon-14 contribute significantly to exposure. For immersion, cobalt-60, carbon-14, tritium, and all fission product noble gases as listed in Table V of Reference 21 are considered.

This represents a maximum value since the assumed releases of Table V are significantly higher than actual. For example, for cobalt-60, the primary radionuclide of interest for NNPP nuclear facilities, the calculations are based on 0.001 curie per year. Table 5-3 shows that the maximum possible release at Subase Bangor occurred in 1988 and totaled $<4.2 \times 10^{-7}$ curie or a factor of about 2000 less.

Comparing the Reference 21 combined dose of 0.0047 mrem/yr to the dose from natural sources of radiation listed in a report published by the National Council on Radiation Protection and Measurements (Reference 6), the calculated combined dose is about 0.0024 percent of that due to airborne natural background radioactivity (primarily radon). When the actual Subase Bangor release values are factored in, the comparative percentage becomes vanishingly small.

Since 1989, PSNS has used the Environmental Protection Agency COMPLY computer program to provide a quantitative estimate of the radiation exposure to which any member of the general public might be exposed as a result of radioactivity in airborne effluents. This analysis is performed in accordance with EPA regulations in 40 CFR 61 Subpart I. Site-specific input parameters include radionuclide releases and distance to members of the public. Cobalt-60 values include actual measurements of cobalt-60 emissions from the exhaust of monitored ventilation in addition to very conservative estimates of other potential sources of cobalt-60. Values for other airborne radionuclides, including iodine-131, are conservative estimates based upon detailed study of land-based Naval nuclear propulsion prototype plants; for example, the very conservative assumption that half of the radioactive water handled evaporates from collection and storage tanks. Thus, the actual exposures to members of the public are expected to be lower than the results of this analysis.

Since the controls for airborne releases have remained the same over the years, the assessment performed by PSNS for Subase Bangor for 1996 can be used for evaluation purposes. The result of the airborne effluent analysis in 1996 was 0.0011 millirem from particulate and gaseous radionuclides and 0.00000048 millirem from radioiodine releases. The estimated maximum radiation exposure to a member of the general public from releases of airborne radioactivity is much less than the standard of 10 millirem per year established by the Environmental Protection Agency in 40 CFR 61.

These comparisons provide additional evidence that the airborne exposure to any potential target due to NNPP activities at Subase Bangor is insignificant.

9.0 **Conclusions**

Evaluation of the information and analytical data presented in this HRA leads to the conclusion that past and current activities at Subase Bangor associated with work on Naval nuclear propulsion plants have had no adverse impact on the human population or ecosystem of the region.

Of all the radiological parameters monitored and reported as part of the long-standing and continuing monitoring of the radiological environment, no cobalt-60 or other radionuclides associated with Naval nuclear propulsion plants have been detected.

The findings and conclusions of the Environmental Protection Agency survey reported in 1989 appear to the Navy to be consistent with the data and conclusions of this assessment, as quoted in Section 6.1.1 and repeated in part below:

> "Based on these surveys, current practices regarding nuclear-powered warship operations have resulted in no increases in radioactivity that would result in significant population exposure or contamination of the environment."

Subase Bangor will continue to follow NNPP radiological control practices and PSNS will continue to perform environmental monitoring as discussed in this HRA. Within the framework of the CERCLA process, no further action is warranted regarding radioactivity associated with the Naval Nuclear Propulsion Program at Subase Bangor.

GLOSSARY

GLOSSARY

Aquifer: A saturated subsurface zone from which drinking water is drawn.

CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act of 1980. Legislation that established the Federal Superfund for response to uncontrolled releases of hazardous substances to the environment.

CERCLIS: CERCLA Information System. EPA's computerized inventory and tracking system for potential hazardous waste sites.

Coastal Tidal Waters: Surface waterbody type that includes embayments, harbors, sounds, estuaries, back bays, etc. Such water bodies are in the interval seaward from the mouths of rivers and landward from the 12-mile baseline marking the transition to the ocean water body type.

Conservative: Tending to overestimate any potential negative impact.

CPW: Controlled pure water.

curie: Abbreviated Ci. A unit of measure of the amount of radioactivity equal to 3.7×10^{10} disintegrations per second or 2.22×10^{12} disintegrations per minute.

EPA: U.S. Environmental Protection Agency. The federal agency responsible for action under CERCLA.

Factor: The basic element of site assessment requiring data collection and evaluation for scoring purposes.

FFA: Federal Facilities Agreement. An agreement among the EPA, state, and site detailing the extent and schedule for remedial actions.

Fishery: An area of a surface water body from which food chain organisms are taken or could be taken for human consumption on a subsistence, sporting, or commercial basis. Food chain organisms include fish, shellfish, crustaceans, amphibians, and amphibious reptiles.

G-RAM: General Radioactive Material. Radioactive materials that are not associated with the NNPP.

HEPA filter: High Efficiency Particulate Air Filter. A filter that will remove 99.97% of 0.3 micron particulates from an air system.

GLOSSARY (continued)

HRA: Historical Radiological Assessment. A compilation of site historical radiological data derived from the site environmental monitoring program and other records. This document is intended to be an integral part of a FFA.

HRS: Hazard Ranking System. EPA's principal mechanism for placing sites on the NPL.

IAS: Initial Assessment Study. A study done under the Navy's Installation Restoration program. This study parallels the PA.

kcpm: Thousand counts per minute.

micro: Abbreviated μ. A prefix denoting a one-millionth part (10^{-6}).

micron: A millionth of a meter (10^{-6} m).

milli: Abbreviated m. A prefix denoting a one-thousandth part (10^{-3}).

NESHAP: National Emission Standards for Hazardous Air Pollutants

NNPP: Naval Nuclear Propulsion Program. A joint Navy/Department of Energy program to design, build, operate, maintain, and oversee operation of Naval nuclear-powered ships and associated support facilities.

No Suspected Release: A professional judgment based on site and pathway conditions indicating that a hazardous substance is not likely to have been released to the environment.

NPL: National Priorities List. Under the Superfund program, the list of sites of releases and potential releases of hazardous substances, pollutants, and contaminants that appear to pose the greatest threat to public health, welfare, and the environment.

PA: Preliminary Assessment. Initial stage of site assessment under CERCLA; designed to distinguish between sites that pose little or no threat to human health and the environment and sites that require further investigation.

pico: Abbreviated p. A prefix denoting a one-trillionth part (10^{-12}).

PSNS: Puget Sound Naval Shipyard

R: Roentgen. A unit of exposure. For cobalt-60 radiation, a roentgen and a rem are considered to be equivalent.

rem: Roentgen Equivalent Man. A measure of radiation dose.

GLOSSARY (continued)

SARA: Superfund Amendments and Reauthorization Act of 1986. Legislation which extended the Federal Superfund Program and mandated revision to the HRS.

Subase: Naval Submarine Base Bangor.

Surface Water: A naturally-occurring, perennial water body; also, some artificially-made and/or intermittently-flowing water bodies.

Suspected Release: A professional judgment based on site and pathway conditions indicating that a hazardous substance is likely to have been released to the environment.

Target: A physical or environmental receptor that is within the target distance limit for a particular pathway. Targets may include wells and surface water intakes supplying drinking water, fisheries, sensitive environments, and resources.

Target Distance Limit: The maximum distance over which targets are evaluated. The target distance limit varies by pathway; ground water and air pathways -- a 4-mile radius around the site; surface water pathway -- 15 miles downstream from the probable point of entry to surface water; soil exposure pathway -- 200 feet (for the resident population threat) and 1 mile (for the nearby population threat) from areas of known or suspected contamination.

Target population: The human population associated with the site and/or its targets. Target populations consist of those people who use target wells or surface water intakes supplying drinking water, consume food chain species taken from target fisheries, or are regularly present on the site or within target distance limits.

Terrestrial Sensitive Environment: A terrestrial resource, fragile natural setting, or other area with unique or highly-valued environmental or cultural features.

TLD: Thermoluminescent dosimeter. A device for measuring gamma radiation exposure.

Wetland: A type of sensitive environment characterized as an area that is sufficiently inundated or saturated by surface or ground water to support vegetation adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

Worker: Under the soil exposure pathway, a person who is employed on a full or part-time basis on the property on which the site is located. Under all other pathways, a person whose place of full- or part-time employment is within the target distance limit.

< : Less than.

> : Greater than.

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